# GEOTHERMAL INVESTIGATIONS IN IDAHO

## GEOTHERMAL RESOURCE ANALYSIS IN TWIN FALLS COUNTY, IDAHO

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# GEOTHERMAL RESOURCE ANALYSIS

# IN TWIN FALLS COUNTY, IDAHO

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### TABLE OF CONTENTS


Introduction....................................................1
    Purpose and Approach........................................3
  Previous Work.................................................3
    Geologic Studies............................................3
    Geothermal Studies..........................................4
  Climate.......................................................5
  Physiography..................................................5
Geologic Framework..............................................7
  Stratigraphy..................................................8
    General Statement...........................................8
    Pre-Cenozoic Rocks (MPz)....................................8
    Tertiary Idavada Volcanic Group.............................9
      Idavada Ash-Flow Tuffs in the Cassia Mountains (Tiv)....10
      Older Rhyolite (Not Exposed).............................10
      Lacustrine Sediments.....................................11
      Subsurface Alteration and Mineralization.................12
      Shoshone Falls Rhyolite..................................12
    Tertiary and Quaternary Basalts (Tb, QTb and Qb)...........14
  Geochemistry of Idavada Rhyolites............................15
  Tectonics and Structure......................................16
Hydrology of Thermal Systems...................................20
  Aquifer Characteristics......................................20
    Aquifer Testing............................................22
    Water Chemistry............................................23
  Monitoring of Thermal Wells..................................23
  Annual Discharge.............................................36
Preliminary Conceptual Model of the Thermal System.............37
Summary and Recommendations for Further Studies................40

References.....................................................42

## LIST OF FIGURES


| | | |
|---|---|---|
| Figure 1 | Index Map | 2 |
| Figure 2 | Tectonics and Structure | 18 |
| Figure 3 | Generalized Stratigraphy of the Study Area | 21 |
| Figure 4 | Well # 1 Hydrograph | 25 |
| Figure 5 | Well # 2 Hydrograph | 26 |
| Figure 6 | Well # 3 Hydrograph | 27 |
| Figure 7 | Well # 4 Hydrograph | 28 |
| Figure 8 | Well # 5 Hydrograph | 29 |
| Figure 9 | Well # 7 Hydrograph | 30 |
| Figure 10 | Well # 11 Hydrograph | 31 |
| Figure 11 | Well # 12 Hydrograph | 32 |
| Figure 12 | Well # 13 Hydrograph | 33 |
| Figure 13 | Conceptual Model of the Twin Falls - Banbury Thermal System | 39 |


## Tables


| | | |
|---|---|---|
| Table 1 | Well Information and Frequency of Measurements | 24 |


## APPENDIX


| | |
|---|---|
| Appendix A | Driller's Logs |
| Appendix B | Generalized Stratigraphic Section for the Cassia Mountains |
| Appendix C | Chemical Analysis of Idavada Pyroclastics and the Shoshone Falls Rhyolite Techniques and Results |


## Plate 1


Geologic Map

ABSTRACT

Increased utilization of the geothermal resource in the Twin Falls - Banbury area of southern Idaho has resulted in noticeable declines in the artesian head of the system. In order to determine the nature of the declines, a network of wells was identified for monitoring shut-in pressures and temperatures. In addition, a compilation of data and reconnaissance of the areal geology was undertaken in order to better understand the geologic framework and its relationship to the occurrence of the thermal waters in the system.

The geothermal resource of the Twin Falls - Banbury system is characterized by temperatures between 30° and 70°C (86° to 158°F) and shut-in well pressures of 14 to 250 psi. The thermal water occurs in rhyolitic ash-flow tuffs and lava flows of the Tertiary Idavada Volcanic Group. Permeability of the reservoir rocks results from tectonic and cooling fractures, intergranular porosity of the non-welded tuffs and voids left between successive flows. The system is recharged by rain and snow falling on the Cassia Mountains to the south. Northward dipping volcanic strata channel the water toward the center of the Snake River Plain and into northwest trending structure zones which cross the area from Hollister to Banbury Hot Springs. The heat source is thought to be the regionally high heat flow supplemented in parts of the system by deep circulation in structure zones.

The results of the monitoring indicate that while water temperatures have remained constant, the system shows a gradual overall decline in artesian pressure superimposed on fluctuations caused by seasonal use of the system. Well testing and the similarity of hydrographs resulting from well monitoring throughout the area suggest that there are no major hydrologic barriers to thermal water movement in the system and that wells are affected by increases and decreases in utilization of nearby wells.

## DISCLAIMER

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## INTRODUCTION

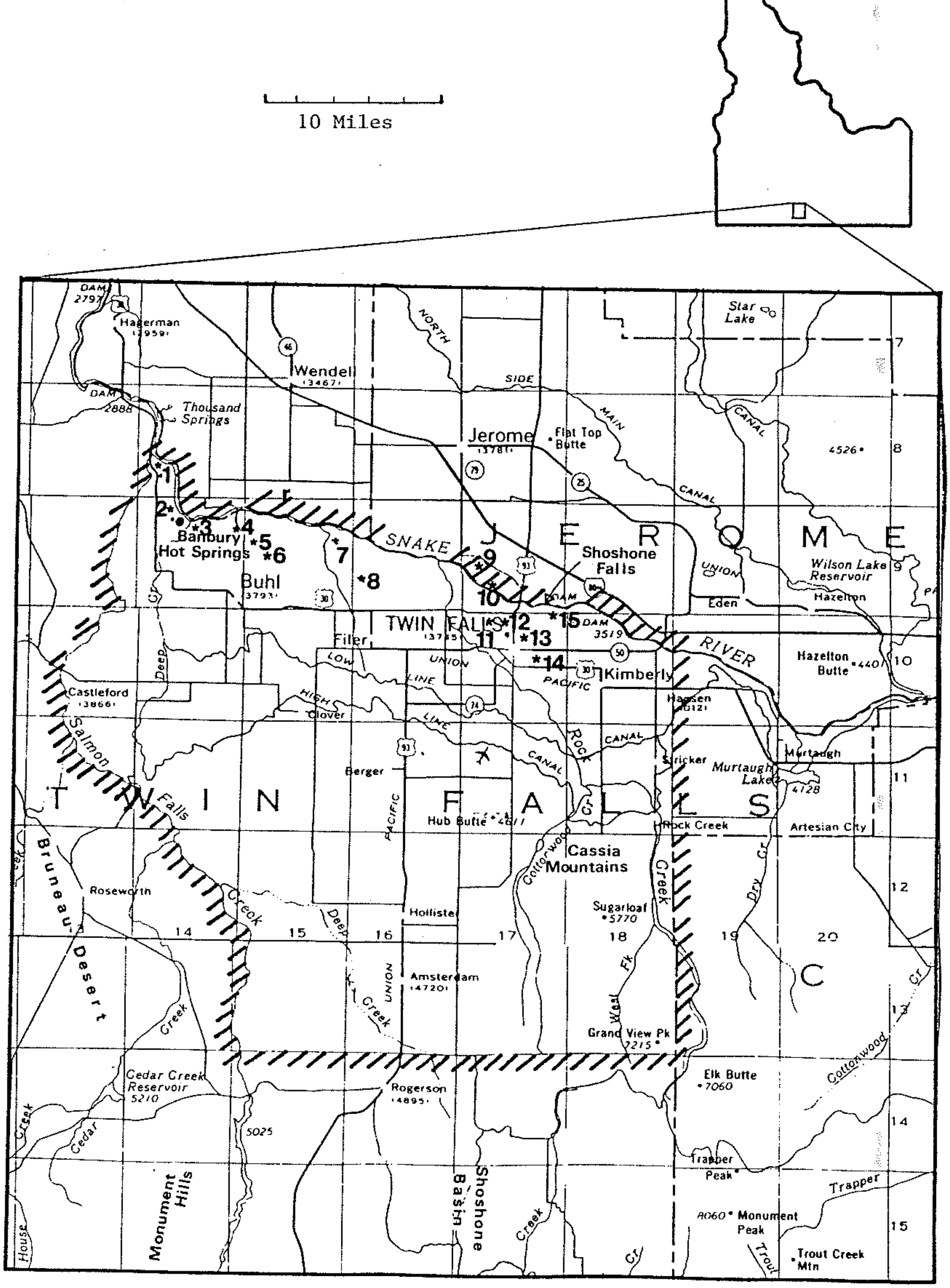
The low to moderate geothermal resource base of the Snake River Plain, Idaho is extensive. Estimates of mean reservoir energy of over 455 x $10^{18}$ J have been made by Mabey (1983) and energy offset of over 26 MW thermal were made by Bloomquist and others (1985). The hydrothermal resources range in temperature from 30 to 70° C (86 to 158°F) and well depths range between 80 and 3000 feet. Most flowing wells have high yields (2000 gpm) and shut-in pressures (250 psi). The focus of this report is the geothermal resources of southern Idaho's Twin Falls County, Figure 1.

Artifacts found in the vicinity of Banbury and other hot springs in Twin Falls County are evidence that thermal waters were known and used by Indians and early settlers. In 1938, a 1154 foot well was drilled by the City of Twin Falls (T10S, R17E, Sec 14 SESWSW) that encountered the geothermal resource. The well continues to be used for irrigation. Further development did not ensue until the early 1970's when concern for energy was heightened. Drilling continued until the early 1980's when projects for low-head hydro-power production, space heating, irrigation and aquaculture were developed. The increased demands on the resource have resulted in noticeable declines in pressure in existing artesian wells. These declines have caused concern among the resource owners, and in some cases have led to litigation.

In the study area, there are more than seventy-five thermal wells. For the convenience of discussion and ease of reference, the wells have been assigned an arbitrary number. The locations of selected wells referred to in this study are shown on Figure 1 and driller's logs for these wells and others are found in Appendix A.

FIGURE 1.

Index Map - Showing Study Area (Inside Hachures), Surrounding Region and Selected Wells



### Purpose and Approach

This study was initiated to provide baseline resource data for the thermal system in Twin Falls County and to develop a model that would describe the relationship between the geothermal resource and the regional geologic framework. Methods selected to complete the objectives were: 1) compile data for existing wells; 2) analyze well logs for thermal water levels and subsurface geology; 3) compile and interpret geologic mapping in relation to regional stratigraphy and structural controls of the system and possible recharge areas; 4) establish a monitoring network using existing thermal wells to record pressure and temperature measurements on a regular basis; and 5) collect samples of the suspected rhyolite reservoir rock for geochemical analysis and comparison.

## Previous Work

### Geologic Studies

Geologic mapping within the study area has been limited to reconnaissance studies. For the southern part of Twin Falls County, virtually no published geologic maps exist at a scale of less than 1:250,000. Also, the nature and stratigraphy of the Idavada rhyolites exposed throughout the area are largely unknown.

The early geologic work in the Snake River Plain included reconnaissance level studies of geology by King (1878), Lindgren (1898), Russell (1902), Schrader (1912), and Buwalda (1924). Stearns and others (1938) published a report on eastern Snake River Plain geology and groundwater resources that included descriptions of the basalts of the lava plains and the Tertiary volcanic rocks at Shoshone Falls. Stearns, in a later publication (1955), described the mud flow associated with the Shoshone Falls volcanic rocks. Youngquist and Haegele (1956) published a report and very general geologic map of the Cassia Mountains. Malde and Powers (1962) studied and defined the stratigraphic framework for the western Snake River Plain and developed much of the stratigraphic terminology and nomenclature currently in use. As part of their reconnaissance of the western Snake River Plain, Malde and others (1963) included much of the western portion of the study area on a geologic map at a scale of 1:125,000. Malde and Powers (1972) published a more detailed geologic map of a part of the previously mapped area, which included the Banbury Hot Springs area, at a scale of 1:48,000. Covington (1976), published a 1:24,000 scale geologic map which focused on geologic hazards along the Snake River Canyon in the Twin Falls area. Stratigraphic relations of Paleozoic and Mesozoic marine sedimentary rocks in the Cassia Mountains were presented by Mytton and others (1983). A study and morphometric analysis of basalt volcanoes in the southern and western portion of the study area was conducted by Jenks in 1984.

## Geothermal Studies

The geothermal resources of the Banbury and Artesian City areas were first described by Stearns, and others (1938). Young and Mitchell (1973) sampled hot springs and wells in Twin Falls County as part of a statewide reconnaissance of geologic setting and chemical characteristics of thermal waters. Lewis and Young in 1980 and 1987 (in press) investigated hydrologic conditions of thermal waters in the Banbury and Twin Falls area using geophysical studies and water chemistry. The geothermal resources in the Artesian City area were studied by Struhsacker and others (1983).

## Climate

The climate of the area is characterized by hot, dry summers [>32°C(90°F)] and cold winters [<7°C(20°F)]. The mean annual temperature at Twin Falls is 9°C(49°F) (U.S. Department of Commerce, 1973). Mean annual precipitation ranges from 9.5 inches at Twin Falls (U.S. Department of Commerce, 1973) to over 40 inches (Wilson and Carstens, 1975) in the mountainous areas to the south. The majority of the precipitation falls as rain or snow during the winter.

## Physiography

The Twin Falls - Banbury Study Area is within the Snake River Plain subdivision of the Columbia Plateaus physiographic province (Fenneman, 1946). The Snake River Plain is an arcuate structural and topographic depression extending across southern Idaho from Weiser on the west to Yellowstone National Park on the east. Recent workers have further subdivided the plain as consisting of a western graben, eastern downwarp, and central transition zone (Mabey, 1982). The Twin Falls - Banbury Study Area lies within the transition zone between the eastern and western subdivisions. Topography of the plain is subdued and includes extensive lava plains and numerous constructional volcanic features including basaltic cinder cones and broad shield volcanoes. Elevations of the Snake River Plain range from 2,000 feet on the west to 5,000 feet near the eastern end.

The area in and around Twin Falls County, like much of the eastern Snake River Plain, is characterized by a gently rolling lava plain from which rise scattered shield volcanoes such as Hansen, Stricker, Hub, Sonnichsen and Flat Top Buttes (see Plate 1). These volcanic shields generally rise from 150 to 400 feet above the surrounding plain (Jenks, 1984). Many of the younger Pleistocene lavas on the north side of the Snake River Canyon still preserve features such as pressure ridges and aa and pahoehoe lava surfaces. On the south side of the river the lavas are earlier Pleistocene and Pliocene and most original features have been removed by erosion or obscured by loess (Covington, 1976).

Within the study area the plain extends south from the Snake River approximately 15 miles to the Cassia Mountains (locally known as the South Hills or Rock Creek Hills). The Cassia Mountains are a broad domal uplift that rise from a base elevation of 4200 feet at the point where Rock Creek enters the plain to a maximum of over 8000 feet at Monument Peak. The uplift contains a core of Paleozoic marine sedimentary rocks that are unconformably mantled by a sequence of outwardly dipping Tertiary ash-flow tuffs. The dome is deeply dissected by numerous drainages.

The southwest and western portion of the Twin Falls - Banbury Study Area is a gently rolling lava plain broken by low shield volcanoes. In addition, these areas are transected by a series of low (50 to 100 foot) northwest trending fault scarps and low elongate shield-like ridges formed by basaltic fissure eruptions.

The Snake River is the primary drainage for the study area. Through the Twin Falls reach, the river has incised a nearly vertical walled canyon 500 to 600 feet deep and 1475 to 4900 feet in width. Important tributaries within the study area include Rock Creek and Salmon Falls Creek. Rock Creek is the primary drainage of the Cassia Mountains where it has carved a canyon in excess of 1450 feet deep. Numerous other less dramatic but deeply incised drainages issue from the Cassia Mountains in a radial pattern. Between the Cassia Mountains and the Snake River, Rock Creek Canyon is relatively shallow (30 to 50 feet) but steep walled. The canyon of Salmon Falls Creek, which borders the study area on the west, is deeply incised with depths in excess of 500 feet. The remaining drainage for the area consists of a series of shallow drainageways that have developed along fault scarps and in the creases between lava flows and shield volcanoes.

## GEOLOGIC FRAMEWORK

Rocks exposed in the Snake River Plain are predominantly the products of bimodal basalt-rhyolite volcanism during the past 12 million years (Leeman, 1982). These volcanics were erupted onto a region of probable low relief which was underlain by folded and faulted pre-Cenozoic sedimentary, volcanic, and plutonic rocks (Armstrong, 1978). Inception of volcanism in any one area of the plain was characterized by voluminous explosive eruptions of rhyolitic ash which resulted in extensive sheets of welded tuff. These were followed by extrusions of rhyolite lavas with some minor intercalated basalts. The final phase of volcanism for an area was the eruption of basalt lavas. Based on radiometric dating (Armstrong, 1975; Armstrong and others, 1975; Armstrong and others, 1980; Honjo and others, 1986), volcanism has progressed along the axis of the eastern plain from the Owyhee Plateau area on the southwest to Yellowstone on the northeast. Recent evidence, including measurements of flow directions in welded tuffs along the margin of the plain (DeTar and Street, unpub. data; Leeman, unpub. data) and additional radiometric dating (Honjo and others, 1986), points to the probability that this general progression was interrupted by regressions or coeval activity at more than one eruptive center.

# Stratigraphy

## General Statement

The oldest rocks in the study area are Paleozoic and Mesozoic marine sediments that form the core of the Cassia Mountains on the southern margin of the Snake River Plain (Rember and Bennett, 1979; Mytton and others, 1983). Tertiary rhyolitic volcanic rocks of the Idavada group mantle the pre-Cenozoic sediments in the Cassia Mountains and underlie most of the Snake River basalts. Tertiary rhyolites comprise the known basement rock within the Snake River Plain portion of the study area and are the reservoir rocks for the Twin Falls - Banbury geothermal system. The Tertiary rhyolite is overlain by 500-700 feet of Tertiary and Quaternary basalts. Lacustrine and fluvial sedimentary rocks of the Glenns Ferry and Bruneau formations are interbedded with and overlie the basalts in the western portion of the study area (Malde and Powers, 1962). The following description of the major rock units focuses on rocks of the Idavada Volcanic Group because of their relationship to the Twin Falls - Banbury geothermal system. Descriptions of the other rock units are more generalized and are included to provide a more complete picture of the stratigraphic framework of the study area.

## Pre-Cenozoic Rocks (MPz)

Paleozoic and Mesozoic sedimentary rocks are exposed both on the northern and southern margins of the eastern Snake River Plain and probably formed a continuous terrain across the area prior to the inception of the Miocene rhyolite volcanism (Armstrong, 1978). Within the study area, the pre-Cenozoic sediments are exposed in the core of the Cassia Mountain uplift. Based on these exposures the pre-volcanic topography was probably a gently rolling to mountainous upland (Struhsacker and others, 1983). Numerous pre-Tertiary episodes of tectonic deformation have resulted in the sediments being folded and thrust faulted.

The units in the Cassia Mountains consist of limestone, dolomitic limestone, siltstone, quartzite, and chert. The limestones and dolomitic limestones range from light to dark gray and fine to medium grained and occur in thick massive beds several to several tens of feet thick. Chert occurs as thin interbeds, as major members of formations, and as nodules and pods up to several feet across within limestone units. Siltstones show a wide range of colors including reddish brown, yellow, and gray, and commonly occur as a series of thin laminar beds. Quartzites are buff, reddish and gray-green, fine to medium grained and massively bedded.

## Tertiary Idavada Volcanic Group

The oldest volcanic rocks in the study area have been mapped as part of the Tertiary Idavada Volcanic Group (Rember and Bennett, 1979; Malde and Powers, 1962). The Idavada Group is a loosely defined aggregation of predominately rhyolitic welded ash-flow tuffs with subordinate amounts of rhyolite lava and intercalated tuffaceous lacustrine sediments (Malde and Powers, 1962). Rocks of the Idavada Group are exposed in the study area within the Snake River Canyon near the City of Twin Falls, in the Cassia Mountains 10 to 15 miles to the south, and in various stretches of Salmon Falls Creek to the west. Idavada rocks have also been mapped in areas along the northern margin of the Snake River Plain (Malde and others, 1963). While rocks of the Idavada group are clearly related genetically, they probably represent numerous as yet undifferentiated episodes of volcanism ranging in age from 12 million years to as young as 6 million years (B. Bonnichsen, personal communication).

Idavada Ash-Flow Tuffs in the Cassia Mountains (Tiv)

Unconformably overlying the Paleozoic and Mesozoic sediments in the Cassia Mountains are a sequence of welded vitric and vitric-crystal rhyolite ash-flow tuff sheets of Miocene age (J. W. Mytton and others, unpub. geologic map). The sequence consists of seven or more distinct cooling units, most of which are separated by variable amounts of poorly consolidated airfall, water-lain, and non-welded ash-flow tuff (DeTar and Street, unpublished data). Thicknesses of the welded tuffs range from 15 feet to over 200 feet. The densely welded units are distinctly zoned, consisting, in ascending order, of: (1) gray bedded surge deposits; (2) gray to black basal vitrophyre; (3) brown, reddish-brown, red and purple massive to platy thick densely welded central lithoidal zones; and (4) an upper lithoidal zone containing abundant primary flow marks and secondary flow folds. Thin gray to black vitrophyre also occurs irregularly at the tops of some units. Phenocryst assemblages and percentages are variable from unit to unit but are generally dominated by plagioclase with minor amounts of pyroxene, quartz, and opaque oxides (probably magnetite and ilmenite) (DeTar and Street, unpub. data).

A generalized stratigraphic section for the Cassia Mountains sequence is presented as Appendix B and is based on a reconnaissance level investigation of exposures along Goat Springs Creek (T13S, R17E, Sec 17) and Dry Gulch (T12S, R18E, Sec 2 & 3).

Older Rhyolite (Not Exposed)

All of the wells in the Snake River Plain portion of the study area that have been drilled deep enough to completely penetrate the Cenozoic basalts encounter Idavada rhyolite. Data for these rhyolites are generally meager, consisting primarily of well cuttings, driller's logs, and discussions with drillers. The descriptions in this report are based primarily on information from wells. Direct correlation of these units with the welded tuff sequence of the Cassia Mountains is not possible because of the extensive basalt cover between the wells and the mountains, the possibility of intervening subsurface structures between the two areas, and the lack of detailed stratigraphic information for the subsurface units in the study area.

Cuttings from the USGS test well at Filer were examined for this study. The cuttings were sand to pebble size making it impossible to determine the large scale features of the rocks. However, it was possible to identify vitric and lithoidal phases of rhyolitic composition. Constituents include abundant glass shards and clear glassy feldspar. Glass shards are cuspate and platy and commonly show bubble wall structure. Other constituents include black and brown 0.01 inch rounded obsidian fragments which are similar to the "apache tears" that commonly occur in perlitic vitrophyres of the Idavada welded tuffs in the Cassia Mountains. Fragments in some intervals, both crystals and glass, are partially to completely coated with a white chalky encrustation. Also noted in the cuttings were minor amounts (less than 1%) of pumice fragments and masses of glass shards welded together.

## Lacustrine Sediments

Wells drilled in the Filer (No. 8, Figure 1) and the City of Twin Falls area (No.'s 11, 12, 13, 14 and 15) encounter a 50 to 100 foot section of white to tan tuffaceous probable lacustrine siltstone and clay-stone overlying the Idavada rhyolites. Cuttings from the USGS test well contain abundant calcareous oolites or coated grain sands similar to exposed Tertiary and Quaternary lacustrine sediments in the western Snake River Plain (Swirydczuk and others, 1979; W. Burnham, personal communication). The oolites or coated sand grains make up approximately 20 to 40 percent of the sample.

The lower part of the lacustrine section as encountered in the USGS test well is a white sugary, vitreous, highly silicified unit containing scattered 0.02 to 0.03 inch masses of opaque oxides, some of which have a halo of limonite. Because the samples were limited in quality and quantity, little else is known about this unit.

## Subsurface Alteration and Mineralization

In the subsurface rhyolite and lacustrine sediments described above, evidence of alteration and mineralization was noted including the white chalky encrustation, fragments and coatings of opal and chalcedony occurring within rhyolite, and magnetite within a probable silicified sedimentary unit. The opal, chalcedony, magnetite, and silicification are the products of hydrothermal activity. However, based on the existing samples it is not possible to determine whether the occurrences are related to the present thermal system or to hydrothermal activity associated with volcanism. The white chalky encrustation may represent paleo-episodes of duricrust formation.

## Shoshone Falls Rhyolite

A silicic volcanic unit of Idavada affinity is exposed in the Snake River Canyon from the Canyon Springs Golf Course (T9S, R17E, Sec 33 NW) to approximately 1/2 mile west of Twin Falls dam (T10S, R18E, Sec 4) and is identified as a single rhyolite lava flow. The rock is light to dark gray on fresh surfaces and weathers to a dark reddish brown. Fracturing occurs throughout the unit. Zones of sheeted or platy fractures are common. Sheets or plates within the zones are generally from 0.5 to 2 inches thick and the zones may be quite extensive covering several hundreds of square feet. Columnar jointing isn't pronounced, but strong vertical fractures are abundant. The bottom of the flow is not exposed but well drilling has shown the flow to be as much as 600 feet thick.

Microscopic examination, as reported by Stearns and others, (1938), and confirmed in this study, has revealed no definitive criteria on which to distinguish this unit as a lava or tuff. Bonnichsen (1982 a & b) has found that many of the tuffs and lavas of the Idavada group are petrographically indistinguishable. Phenocrysts in the porphyritic rock are predominately plagioclase with minor amounts of pyroxene and opaque oxides. The plagioclases are milky white in hand specimen and are up to 0.2 inch in length. The pyroxenes and oxides are commonly closely associated and phenocryst aggregates of plagioclase, pyroxene and oxides, are common but widely scattered. Bonnichsen (1982b), notes that phenocryst aggregates in general tend to be more abundant in lava flow rocks than in welded tuffs, but more detailed statistical analysis will be needed to establish the greater abundance of the aggregates in this unit.

These rocks have been classified (Stearns, 1955; Stearns and others, 1938) as an andesite lava flow. Classification of this unit as a lava flow was based on the abundance of glass near the top of the unit, the abundant vesicles, and the common flow structures. However, all of these characteristics can also be found in the ash-flow tuffs of the Idavada group in areas north and south of the Snake River Plain. Further evidence suggesting that this unit is a lava flow rather than an ash-flow tuff, is the lobate morphology, irregular upper surface of the unit, the irregular distribution of vitrophyre and breccia zones within the unit, the lack of typical ash-flow tuff zonation, and the lack of the characteristic ash-flow tuff tabular aerial distribution.

While Stearns' classification of this unit as a lava flow can be supported, it is believed his classification of the rock as andesite is incorrect within the context of current classification schemes. Based on the phenocryst assemblage, which is typical of Idavada group rocks, and geochemical analyses (see Appendix C, samples SF1 and SF2) these rocks should be classified as rhyolite or silicic latite genetically related to the Idavada group.

Tertiary and Quaternary Basalts (Tb, QTb and Qb)

A sequence of Tertiary and Quaternary basalt lava flows overlies the Tertiary rhyolites. The oldest of these basalts includes the type Banbury Basalt of Stearns and others, (1938) which has yielded radiometric ages of 4.4 to 4.9 million years and possibly as old as 6.2 million years, (Armstrong, 1975, contains a good discussion of Banbury Basalt and its various ages and correlations). Near the type locality (Stearns and others, 1938), Banbury Basalt lies unconformably on Idavada rhyolitic rocks (Malde and Powers, 1962). While contact between Banbury and Idavada rocks is not exposed in the Snake River Canyon near the City of Twin Falls, Banbury Basalt is believed to overlie Idavada volcanics over much of the area to the west. However, where the Shoshone Falls rhyolite is exposed in the Snake River Canyon it is not overlain by Banbury Basalt but rather by younger basalts of Glenns Ferry (Plio-Pleistocene) and Snake River (Pleistocene-Holocene) age (Covington, 1976). Therefore, the Shoshone Falls rhyolite marks the eastern limit of Tertiary basalt flows in this area. Banbury Basalt is also exposed in the uplands of the Snake River Plain in the southwest part of the study area and within the Salmon Falls Creek Canyon (Malde and others, 1963).

Banbury Basalt within the study area consists of a series of thin olivine basalt flows which are locally interbedded with minor stream and lake sediments (Malde and Powers, 1972). The basalts are gray to dark gray to gray-green, both dense and vesicular, fine to coarse grained and diktytaxitic (Malde and others, 1963). These older basalts generally are altered. Phenocrysts include amber to brown olivine crystals and clusters of plagioclase 0.01 inch in diameter and laths of plagioclase averaging 0.08 inch in length.

A series of similar appearing, but younger and unaltered basalts, overlie Banbury Basalt in the City of Twin Falls area. These basalts include units assigned to the Glenns Ferry Formation (Malde and others, 1962 and 1963) in the western part of the study area and the younger Snake River Group (Malde and others, 1962; Covington, 1976) of lava flows which were erupted from vents north, south and northeast of Twin Falls. These basalts represent the surface units at the City of Twin Falls and are well exposed along the canyon wall of the Snake River and Rock Creek.

## Geochemistry of Idavada Rhyolites

In order to establish baseline geochemistry for the known and related geothermal reservoir rocks of the area, nineteen samples of ash-flow tuff, airfall tuff and rhyolite lava were analyzed for major element compositions. Of these, nine samples were analyzed for the following trace elements: Sr, Ba, Co, Cu Pb, Zn, Sb, Li, Be, Fr, La, Ce, and F. The variable compositions of the rocks fall within a range comparable to other rhyolitic rocks of the Idavada Volcanic Group (Bonnichsen, 1982a and b; Bonnichsen and Citron, 1982; Ekren and others, 1982; Leeman, 1982). A discussion of analytical techniques and the results of the analyses are presented in Appendix C.

## Tectonics and Structure

Mabey (1982) states that "...the Snake River Plain remains one of the least understood geologic structures in the United States. It has been described as a depression, downwarp, graben, rift, and lateral rift." The plain is clearly related to, and the partial result of the propagation of, bimodal basalt-rhyolite volcanism from southwest to northeast across southern Idaho. Mabey (1982) divides the plain into three subdivisions; an eastern, western, and central segment. The western Snake River Plain graben is clearly expressed topographically and is distinctly bounded by normal faults along its southwest and northeast margins. The eastern Snake River Plain, Mabey concludes, is "likely a downwarp containing a complex of calderas." Ekren and others (1984) considered the eastern Snake River Plain to be part of a tectonic-structural trend extending from the Idaho-Oregon-Nevada border area to Yellowstone National Park and possibly beyond. Within the central segment, graben bounding structures of the western Snake River Plain, but not the pronounced topographic expression, are superimposed on the eastern Snake River Plain trend. The Twin Falls - Banbury Study Area is located within this central segment.

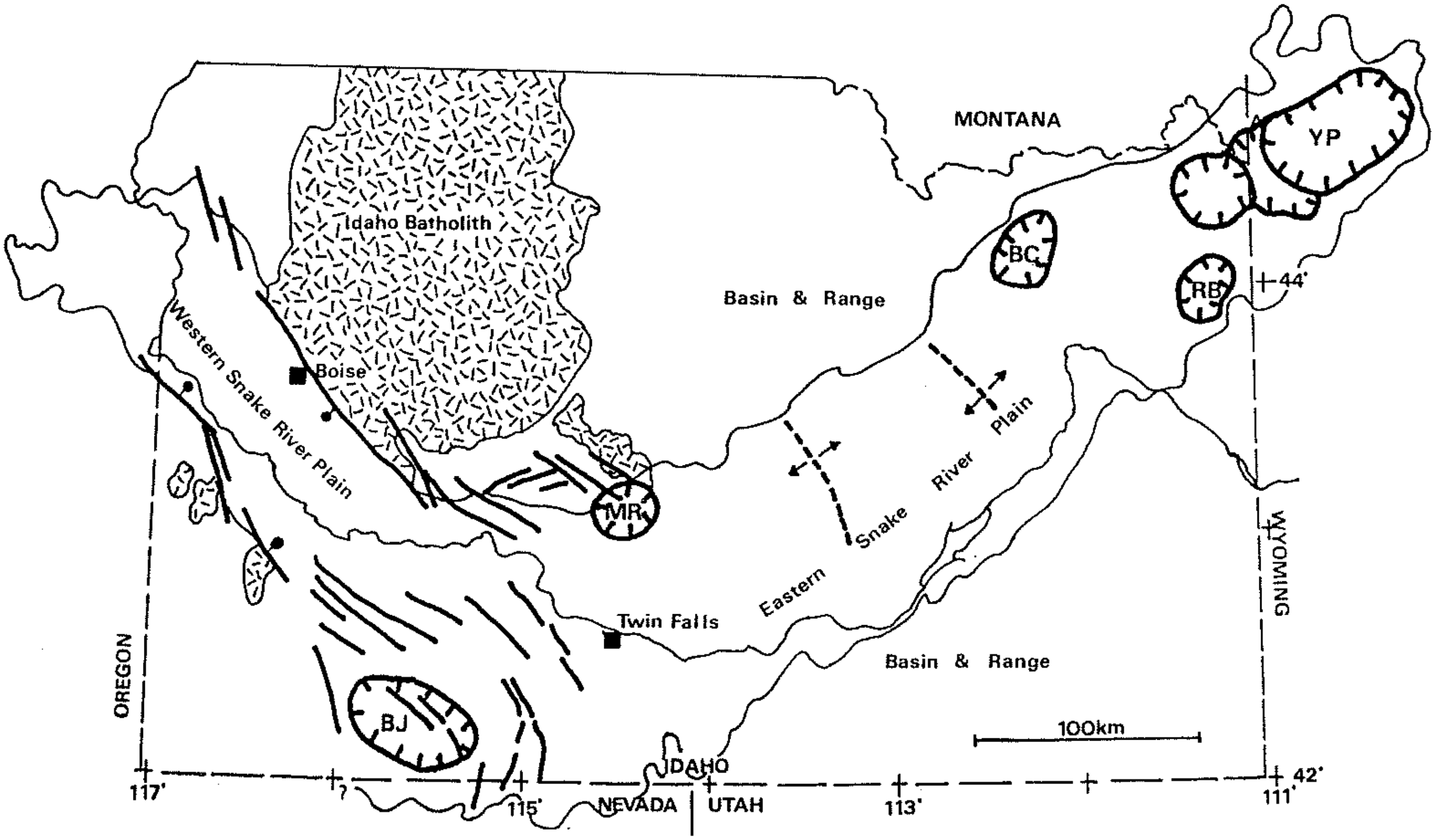
Not only is the gross structure of the Snake River Plain poorly understood, but the local structures within the plain are similarly enigmatic. Basement and subsurface structures are probably complex because of the complex geologic and volcanic history of the area. However, these structures are difficult to completely delineate because they are covered by Cenozoic basalts.

Structural features characteristic of both the eastern and western Snake River Plain occur within the study area. Idavada volcanic strata along the southern margin of the plain, within the study area, dip into the plain and disappear beneath basalt without any clear evidence of down-faulting. A review of the depth at which the top of Idavada rocks is encountered in wells south of the City of Twin Falls demonstrates that this trend continues beneath the basalt cover (Street and DeTar, unpub. data). This is consistent with interpretation of the eastern Snake River Plain as a downwarp.

Western Snake River Plain structures are represented within the southwest part of the study area by a series of northwest trending small displacement (<100 ft.) normal faults and small scale grabens that fan out from the Salmon Falls Creek area across the Bruneau Desert to merge with the fault zone on the southwest margin of the western plain at the base of the Owyhee Mountains (see Figure 2 and Plate 1). These northwest-trending fault zones are characteristic of the structural style within the western part of the study area. The northwest trending faults of the Bruneau Desert and Salmon Falls Creek area form a broad zone of normal faulting which appears to be related to Basin and Range extension. This zone crosses the southwest portion of the study area from Hollister to Buhl and is sub-parallel to rift zones normal to the eastern plain. The rift zones are also thought to be related to Basin and Range extension, (Kuntz, 1977).

The northeastern most trend of the Bruneau Desert - Salmon Falls Creek zone is here informally designated the Buhl-Berger Structure Zone (BBSZ). This N 35° W trending structure zone traverses the area from southeast of Buhl to southeast of Hollister, and is delineated based on the occurrence and trend of fault scarps and associated basaltic eruption fissures, and aligned vents (see Plate 1).

The principal fault scarps within the BBSZ are recognized in the field and on topographic maps as somewhat rounded northwest trending linear ridges which are steepest on the northeast side and slope gradually away to the west indicating a northeast side down sense of movement. There are two primary scarps within the




Compiled from Ekren and Others (1982), Protska and Embree (1978) and Leeman (1982).

Known or Inferred Calderas or Eruptive Centers

Caldera Designations

**YP** - Yellowstone Complex

**RB** - Rexburg Complex

**MR** - Magic Reservoir Caldera

**BJ** - Bruneau-Jarbidge Eruptive Center

**BC** - Blue Creek Caldera

Selected Faults - Ball on downthrown side

Granitic Rocks of the Owyhee Mountains and Idaho Batholith

Rift Zone

Figure 2
Tectonics and Structure

zone, one, 50 to 75 feet high, extending from the southeast corner of Buhl to about Berger (Plate 1) and the second, 150 to 175 feet high, from Clover to just north of Hollister (Malde and others, 1963).

Basaltic fissure eruptions are associated with both of the fault scarp segments, evidence that the BBSZ is probably a deep seated structure. Southeast of Hollister, three aligned basaltic shield volcanoes lie on trend with the BBSZ and appear to represent an extension of the zone. The zone cannot be traced with any certainty into the Cassia Mountains. A graben which forms the Shoshone Basin (Figure 1) is a possible southeast extension of the zone, but this interpretation is complicated by a possible east-northeast trending structural zone that has been identified trending across the northern margin of the Monument Hills and into a zone of concentrated and possibly faulted basaltic vents including Salmon Falls Butte (Figure 1), (Covington, U.S. Geological Survey, unpublished mapping; Bonnichsen & Jenks, Idaho Geological Survey, personal communications). This east-northeast trending zone may offset structures in the Cassia Mountains and Monument Hills (Figure 1) from those in the plain and it appears to at least mark a change in structural style and trend.

On the northwest the BBSZ can be traced to a zone of northwest trending faults mapped by Malde and others, (1963) through the Banbury Hot Springs - Melon Valley area. The BBSZ and the extension mapped by Malde and others, (1963) coincide with a major bend in the Snake River and the sense of movement (down to the northeast) is appropriate for fault control of this deflection of the river.

In some areas of the Snake River Plain alignment of basaltic cinder cones and/or shields can be used to delineate structures such as the BBSZ. Probably most basalt volcanoes in the Snake

River Plain are related to deep seated fractures. However, basaltic vents in the area northeast of the BBSZ area show no clear pattern of alignment.

The stratigraphy of the study area is summarized in Figure 3. Structurally, the area is complex with a dominant northwest-trend. The stratigraphy and structures both play important roles in understanding the nature and occurrence of the geothermal resource. The following hydrogeology sections discuss the relationship between the geothermal resource and the geologic framework.

## HYDROLOGY OF THERMAL SYSTEMS

### Aquifer Characteristics

The geothermal aquifer of the Twin Falls - Banbury area is a confined artesian system with shut-in pressures ranging from 14 to 250 psi depending upon the elevation of the well. Based upon the drillers' logs, well cuttings and chemistry of thermal water, it is apparent that the system is contained in the Idavada volcanics with the upper units acting as the confining layer. Permeability of the volcanic rocks is the result of structural fractures related to tectonic movements, sheeted cooling joints and fractures developed during emplacement, intergranular porosity of the non-welded ash flows and air fall tuffs, and voids left between successive flows.

Where Idavada pyroclastic rocks are exposed, they are composed of a heterogeneous assemblage of rocks. In heterogeneous rocks, it is difficult to accurately calculate transmissivity and storativity values without long-term flow tests. The following section describes the data obtained from the only long-term flow test on the aquifer near Twin Falls.

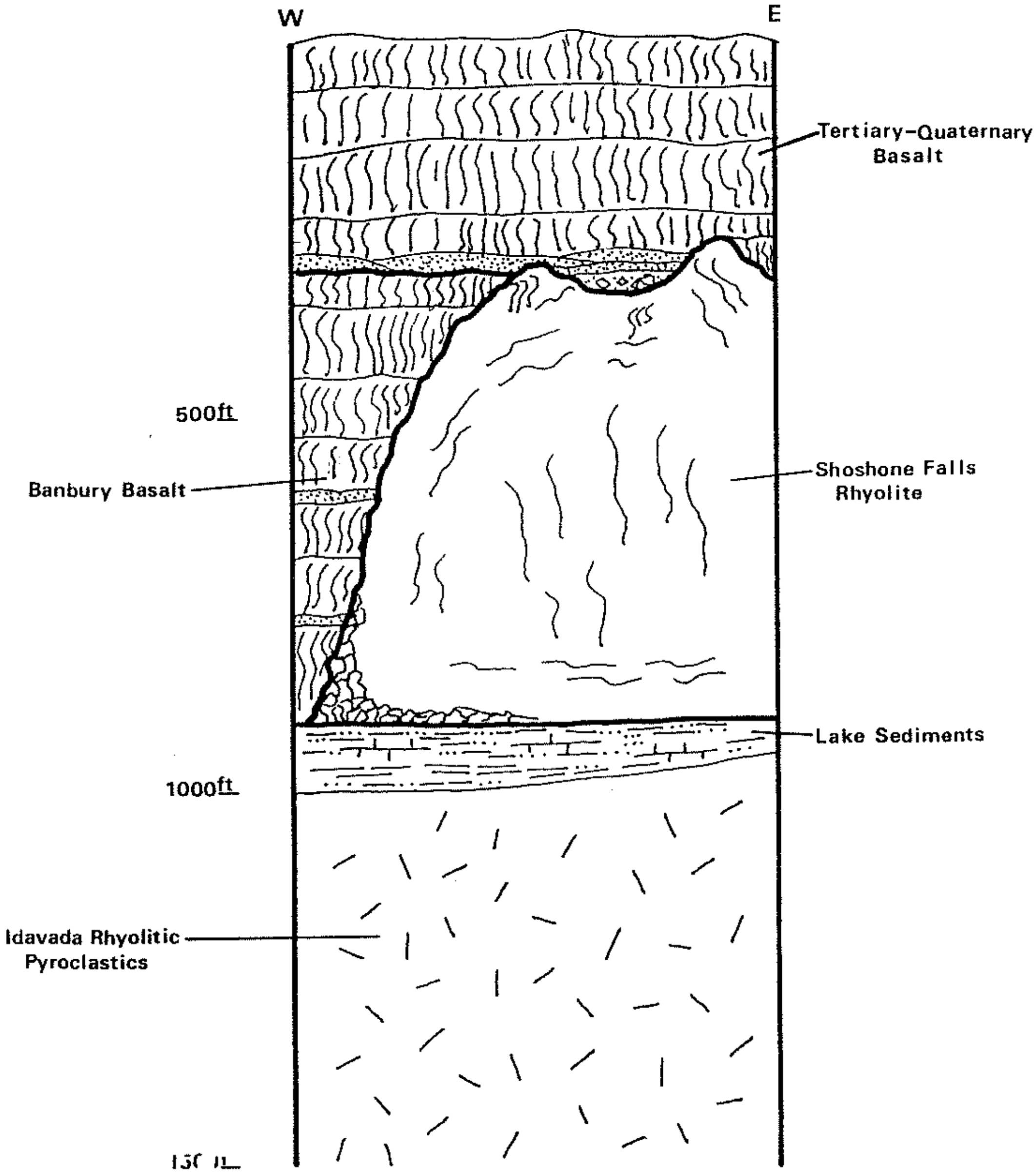



Figure 3

Generalized Stratigraphy of the Study Area

## Aquifer Testing

A 1000 hour (41.7 days) aquifer test was conducted by $CH_2M$ Hill (unpub. report, 1982) for the developer of the well in T9S, R17E, Sec 33 NWNWNW (Well No. 10) from July 22 to September 2, 1982. During the test, the well-head pressure was maintained at 150 psi which was the pressure that was to be used for production. Periodic measurements of the flow indicated that it remained relatively constant at 2,920 GPM throughout the test.

During the test, shut-in pressures were recorded on the wells in T10S, R17E, Sec 4 (Wells No.'s 11 and 12). At the end of the test, pressures were recorded in the two monitoring wells and the test well for 46 days to determine the rate of recovery. Nearly complete recovery to original static heads was noted in all three wells.

Based on this test, the transmissivity (permeability) and storativity (volume of water taken into or released from storage) were calculated for both recovery and drawdown and are as follows:

| Well | Data Type | Transmissivity (GPD/FT) | Storativity |
|---|---|---|---|
| 9S 17E 33 #10 | Recovery | 74,300 | - |
| 10S 17E 4 #12 | Recovery | 46,400 | - |
| | Drawdown | 45,200 | $5.8 \times 10^{-4}$ |
| 10S 17E 4 #11 | Recovery | 58,600 | - |
| | Drawdown | 44,600 | $6.2 \times 10^{-4}$ |

From this test and subsequent time drawdown analyses, $CH_2M$ Hill concluded that no hydrologic boundaries exist between the wells and that the development of the well would affect the water levels in nearby thermal wells.

## Water Chemistry

Detailed analyses of thermal water chemistry were not conducted during this study. Previous analyses have shown that the thermal water in the study area is low in Ca, Mg and high in Si, $HCO_3$ and F in comparison to other geothermal waters in the state with different aquifer rock types (Young and Mitchell, 1973).

It has been determined that the Idavada ash flow tuffs are high in $SiO_2$, F and low in Ca and Mg (Appendix C). It is apparent from this that the chemistry of the thermal water reflects the geochemistry of the flowpath and Idavada host rock.

## Monitoring of Thermal Wells

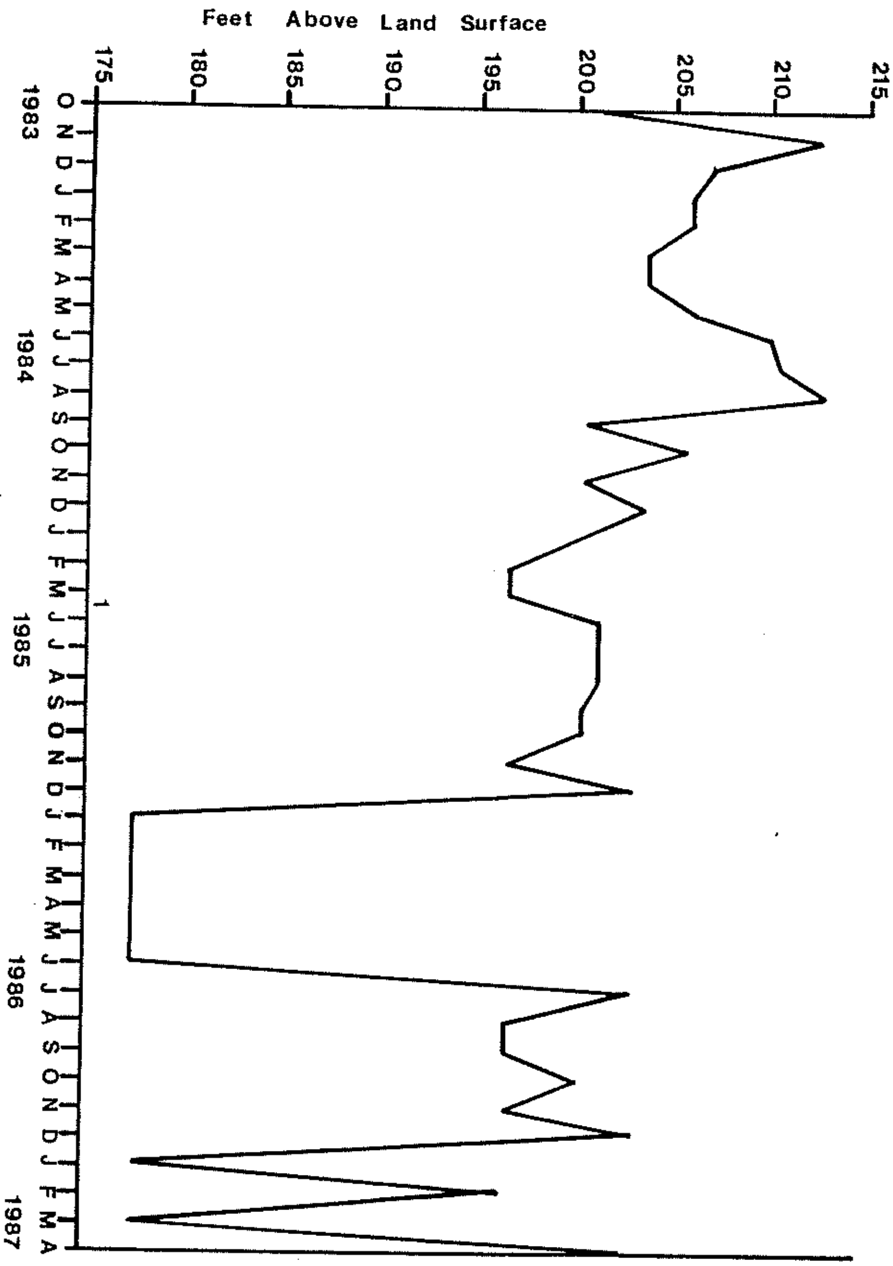
A monitoring network of five wells in the Banbury Hot Springs area was established in the fall of 1983. A similar network of four wells was established for the Twin Falls area in the spring of 1984. A standard method was employed to determine pressure and temperature measurements. The procedure included completely shutting in each well for ten minutes and at the end of this time recording pressure and temperatures. Record was also kept of other information, such as how many valves were opened or comments made by the owner regarding well performance.

The locations of the monitoring wells and other wells discussed in this section are shown in Figure 1. Frequency of measurements and pertinent well information for both the monitored wells and other wells discussed in the text are found in Table 1. The results of the monitoring effort are illustrated by hydrographs (Figures 4 through 12). Temperatures remained constant during the monitoring.

TABLE 1. WELL INFORMATION AND FREQUENCY OF MEASUREMENTS

| WELL NO. | LOCATION | ELEVA-TION | FLUID TEMP. °C/°F | DEPTH | *FRE-QUENCY | PRESENT USE |
|---|---|---|---|---|---|---|
| 1 | 8S 14E 30 NESWSE | 2897 | 68°/154° | 760′ | M | Heating |
| 2 | 8S 14E 33 SWNWSE | 2907 | 47°/117° | 800′ | M | Greenhouse Heating |
| 3 | 9S 14E 04 NWNWNW | 2959 | 41°/106° | 700′ | M | Space Heating |
| 4 | 9S 14E 09 NESESW | 2996 | 32°/90° | 850′ | M | Tropical Fish |
| 5 | 9S 14E 14 NWSENW | 3146 | 34°/93° | 906′ | M | Irrigation |
| 6 | 9S 14E 14 NENESW | 3200 | | 1300′ | | Catfish Propogation |
| 7 | 9S 15E 12 SWSWNE | 3064 | 42°/108° | 1420′ | M | Irrigation |
| 8 | 9S 16E 20 NESESE | 3530 | | 1247′ | | USGS-Observation Well |
| 9 | 9S 17E 29 NWSWSE | 3154 | | 743′ | | Cat Fish Propogation |
| 10 | 9S 17E 33 NWNWNW | 3174 | | 750′ | | Low-Head Power Gen. |
| 11 | 10S 17E 04 SWNWNE | 3662 | 37°/99° | 1453′ | W | Campus Space Heating |
| 12 | 10S 17E 04 SWSENE | 3668 | 37°/99° | 1191′ | W | Campus Space Heating |
| 13 | 10S 17E 10 NWSENW | 3717 | 37°/99° | 1700′ | W | Space Heating |
| 14 | 10S 17E 14 SWSESE | 3786 | | 1154′ | | Irrigation |
| 15 | 10S 18E 06 NWNWNW | 3585 | | 1300′ | | Domestic Space Heating |

* Frequency of Measurements (M=monthly, W+weekly)

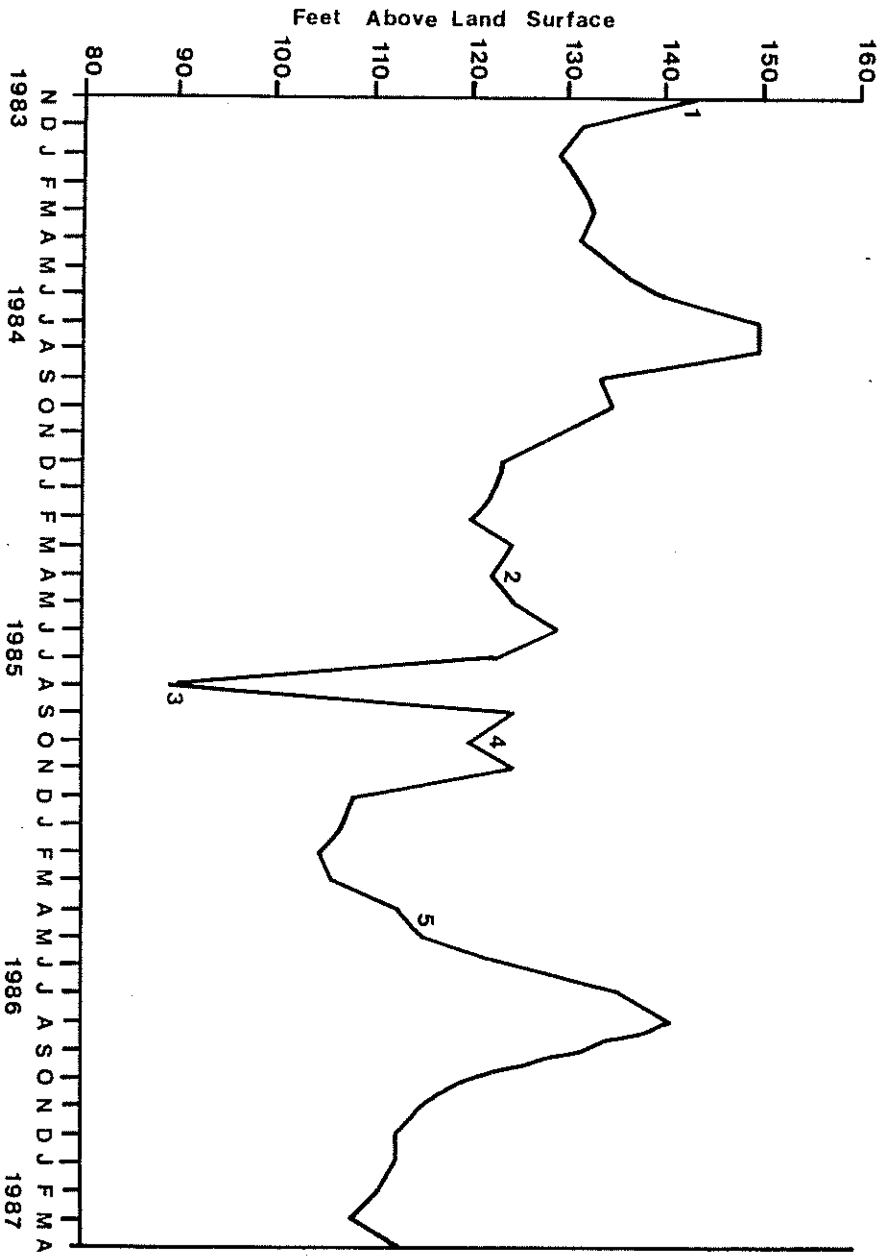



1. No reading possible for April and May

Figure 4

Well #1 Hydrograph

T8S, R14E, Sec. 30, NESWSE




1. Well not in use
2. Greenhouses on line
3. New well being drilled
4. Developing system - adding greenhouses
5. Used for domestic from April through July

Figure 5

Well #2 Hydrograph

T8S, R14E, Sec. 33, SWNWSE

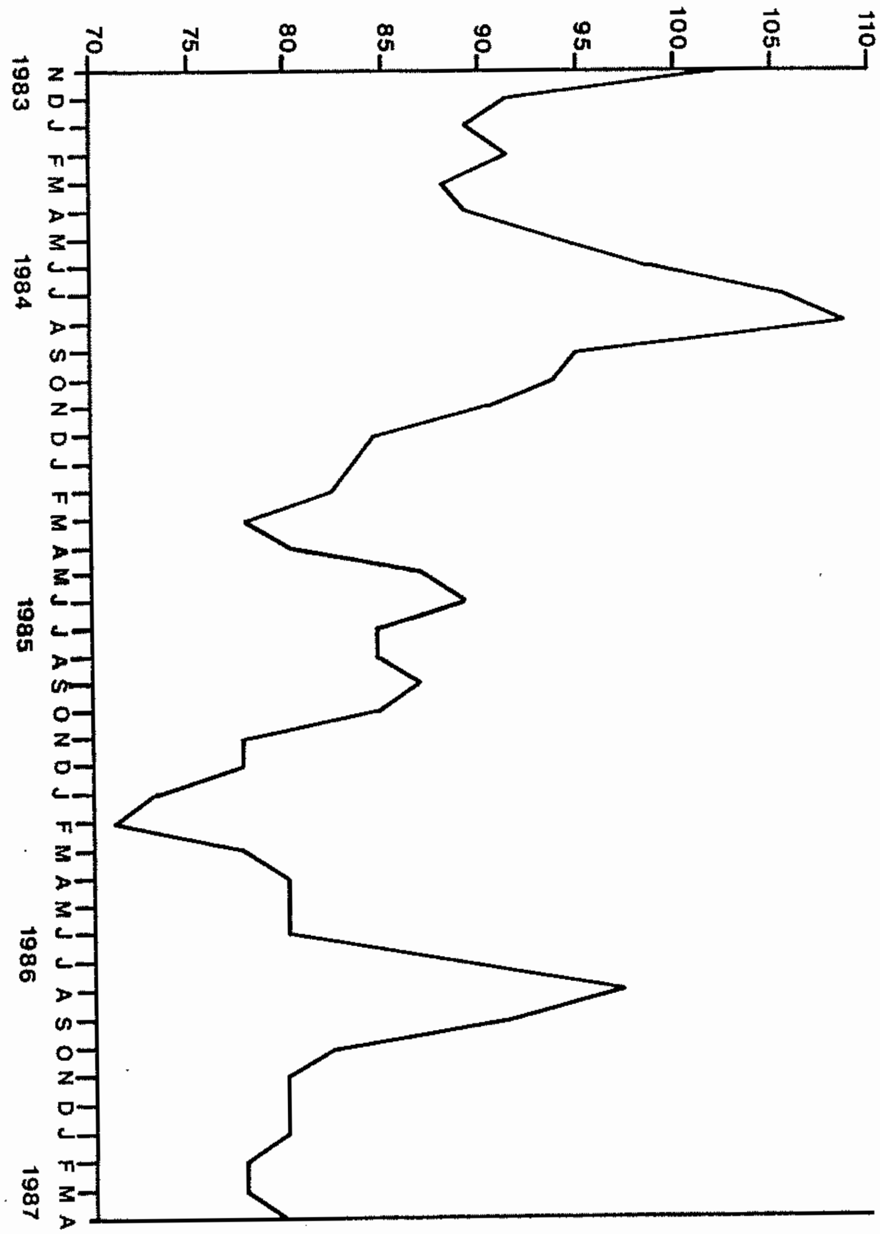
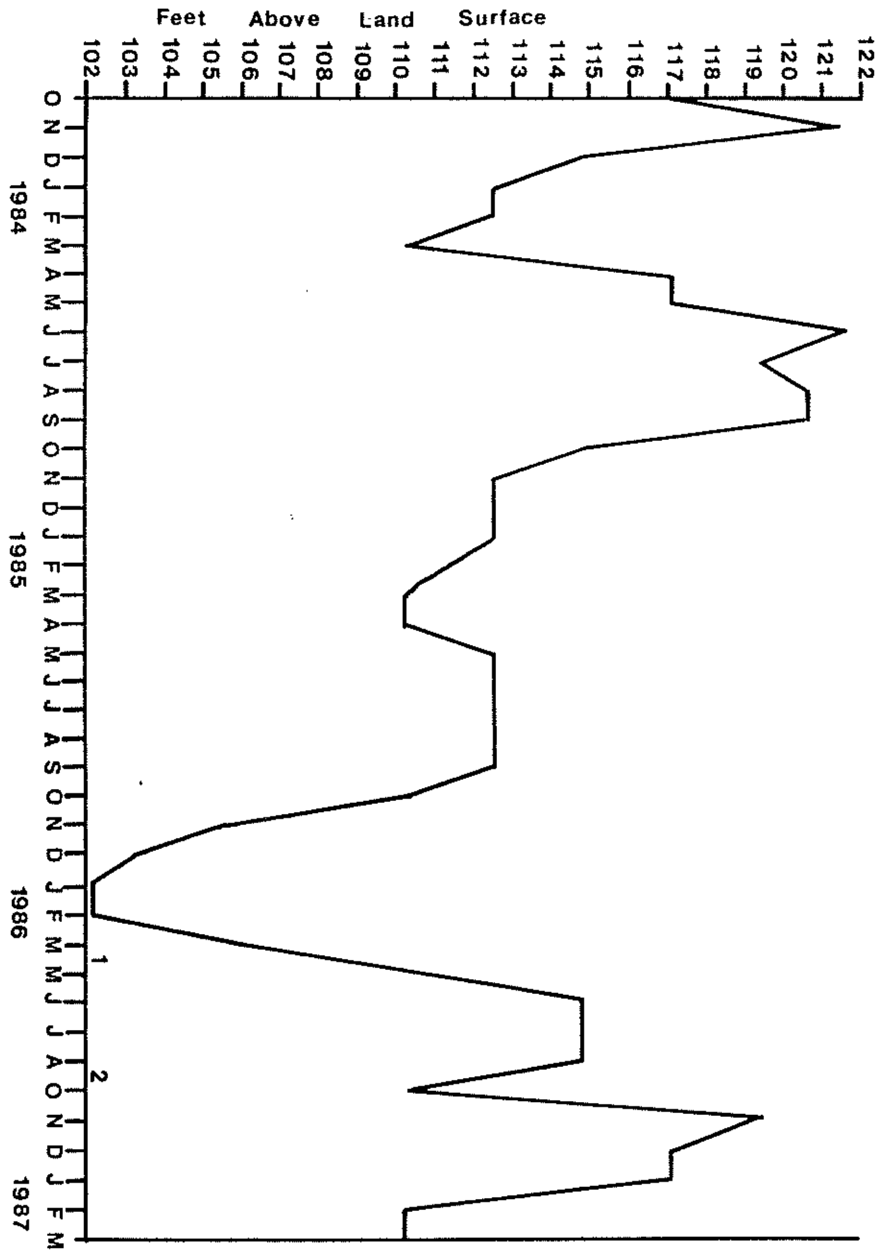



Figure 6

Well #3 Hydrograph

T9S, R14E, Sec. 14, NENESW

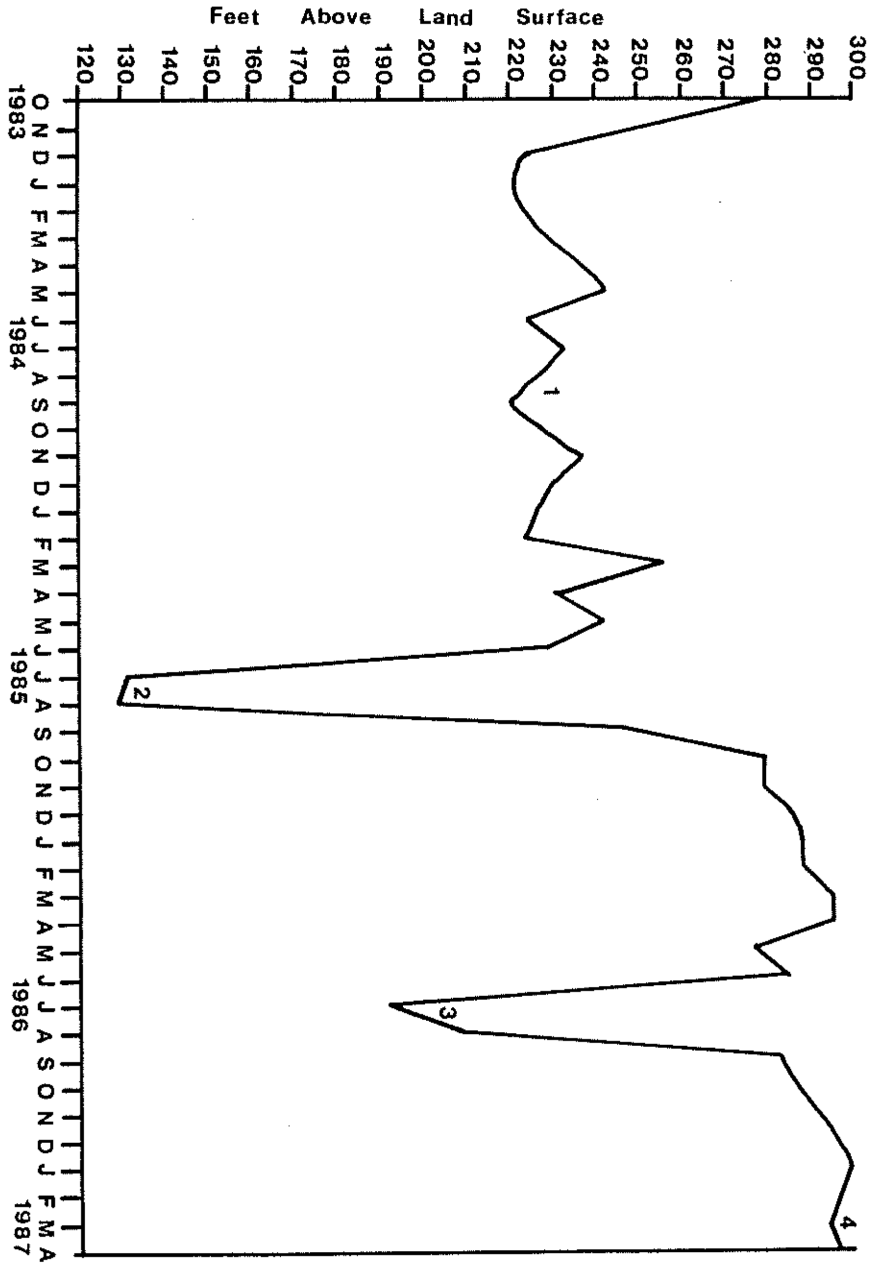



1. No reading for April, 1986
2. No reading for September, 1986

Figure 7

Well #4 Hydrograph

T9S, R15E, Sec. 12, SWSWNE

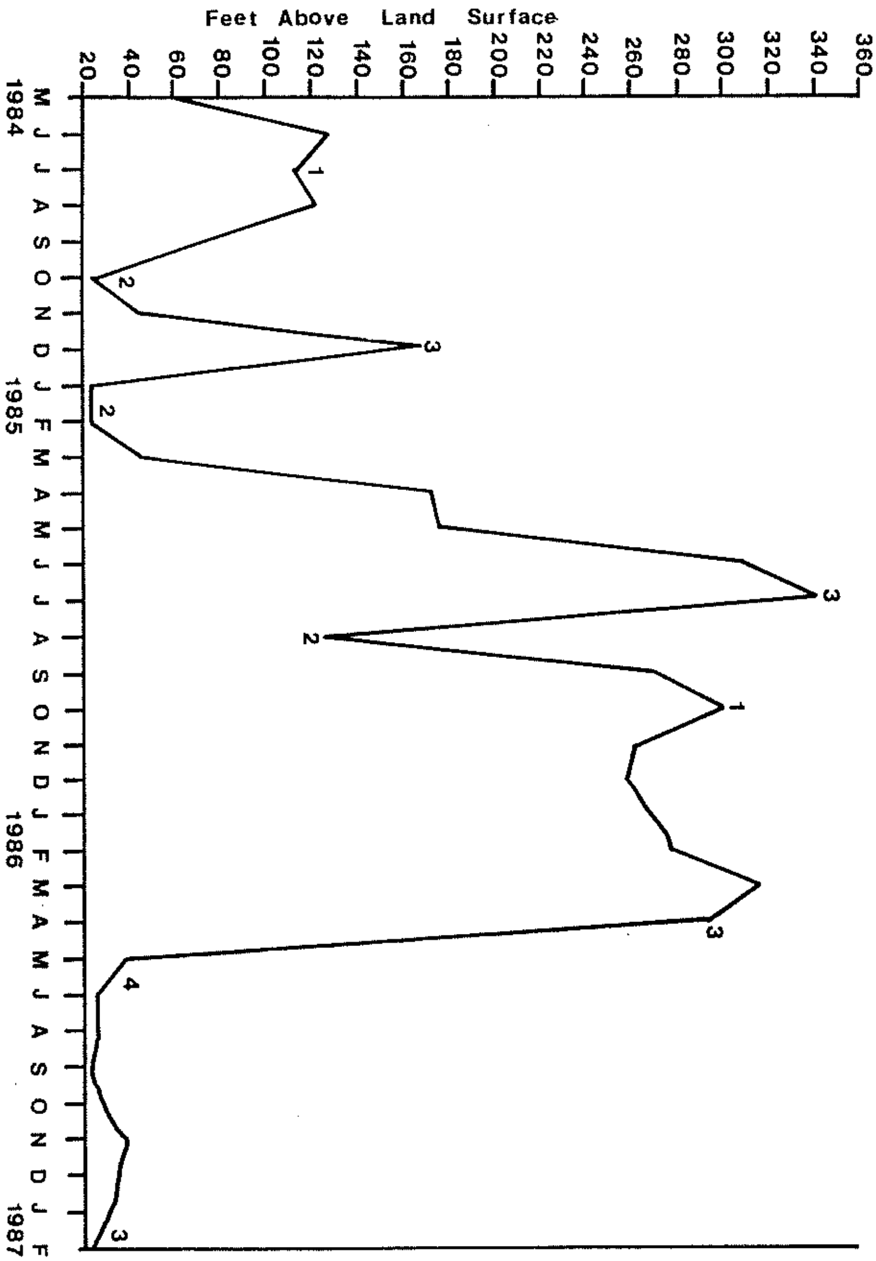



1. Irrigation
2. Irrigation
3. Irrigation
4. Wells in adjacent area are open

Figure 8

Well #5 Hydrograph

T9S, R14E, Sec. 14, NWSENW




1. Small amount flowing
2. Completely open
3. Shut-in
4. Well cleaned out

Figure 9

Well #7 Hydrograph

T9S, R15E, Sec. 12, SWSWNE

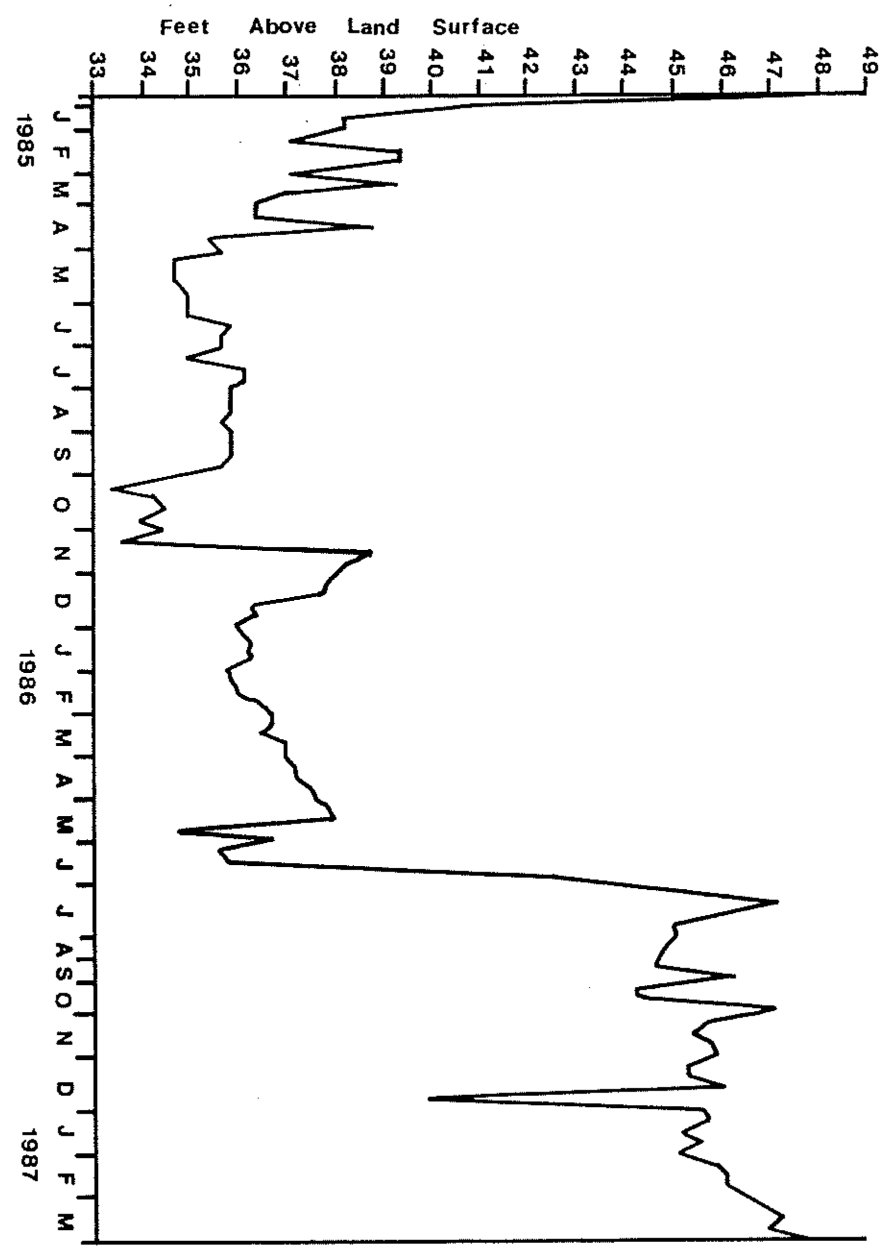
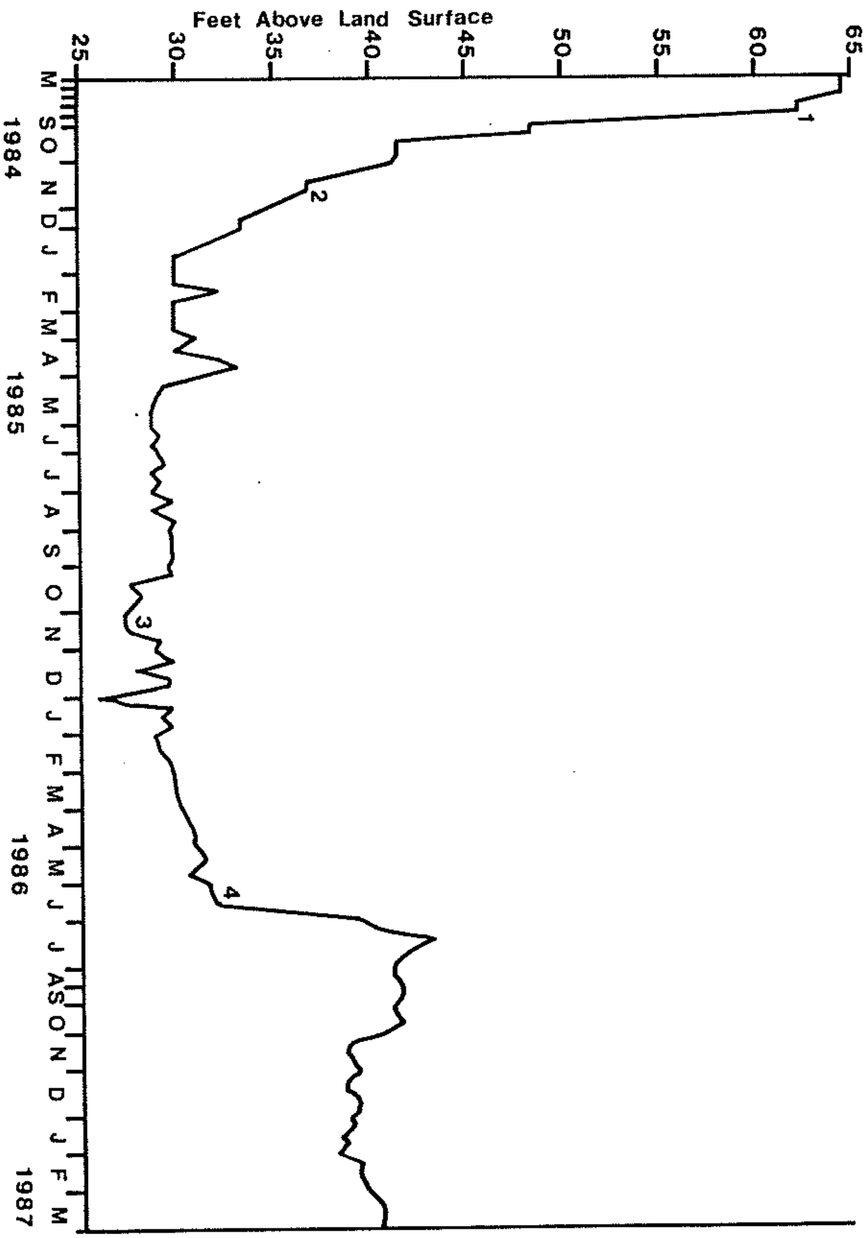



Figure 10

Well #11 Hydrograph

T10S, R17E, Sec. 04, SWNWNE

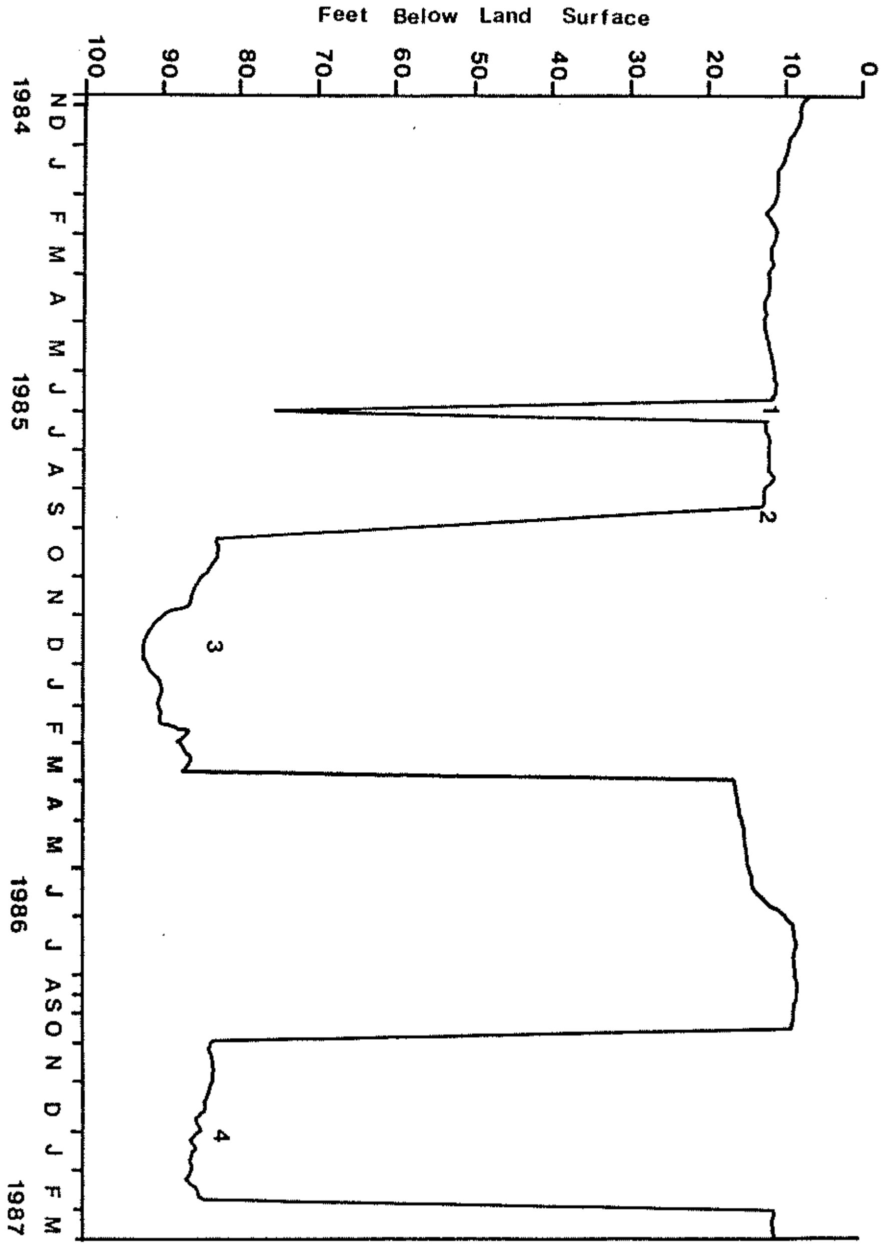



1. Low head power production goes on line from Well #10
2. Well #13 being developed
3. Well #13 goes on line
4. Well #9 repaired

Figure 11

Well #12 Hydrograph

T10S, R17E, Sec. 04, SWNENE




1. Pump test
2. Well being used for heating
3. Pumping levels
4. Pumping levels

Figure 12

Well #13 Hydrograph

T10S, R17E, Sec. 10, NWSENW

Seasonal fluctuations are shown in the hydrographs of wells No.'s 1, 3, and 4 (Figures 4, 6 and 7 respectively). Typically, demand is the greatest during the winter months and recovery occurs in the late summer, early fall. The sharp decline in the months of January and February of 1985 reflects the harsh winter which resulted in increased usage of the geothermal resource.

Well No. 2 (Figure 5) was not used until April, 1984. The record from November, 1983, until that date reflects a shut-in period. The sharp drop in the fall of 1985 represented the time when the owner was testing the system for use in an additional greenhouse. The effect of a new geothermal domestic well drilled in October of 1985 is shown as a depression. From April to the end of June in 1986, the use of the monitored well was expanded to irrigation and domestic consumption because the cold water supply to the area was under repair. This can be seen as a break in the slope of the seasonal recovery.

Well No. 5 (Figure 8) is primarily used for irrigation, hence the deep declines during the summer months. From July to December, 1986, an increase in pressure is shown. This increase was caused by the shut-in of four wells in the adjacent area (T9S, R14E, Sec 14, all 4 wells are shown as No. 6 on Figure 1) that used approximately 4300 gpm from 1983 until late fall, early winter of 1985. Two of the wells were opened and have been utilized since January, 1987 for fish propagation. This subsequent usage is shown by the decline of the water level in the monitored well.

The hydrograph of well No. 7 (Figure 9) is erratic. The well is 1420 feet deep and is cased to 621 feet in poorly consolidated sediments or ash layers. These units continue below the casing where they have the tendency to cave, thus clogging the well. The well was cleaned out during June and July, 1986. Additional casing was not added, therefore the clay continues to clog the well. The well has not been utilized over a continuous period of time. When the well was flowing freely, the 10 minute shut-in pressures were low, as compared to when the well was completely shut-in over a period of time, the pressures were high. This is evident in the reading of June, 1985. At that time, the pressure had increased to the point where water was leaking from the bolts on the well head. Most of the time the well is either opened completely or is running a small amount; rarely is it completely shut in.

During September, 1984, well No. 10 was opened and used for power production. The well produces at a constant rate of 2470 GPM, and has rarely been shut-in for more than a few hours. When production for the power project commenced the response in wells 11 and 12 was immediate as indicated in Figures 10 and 11. The decline continued until the end of the 1984 heating season. Fluid pressure recovery did not return to pre-production levels. Well 13 was drilled and completed in August, 1984 and was pumped at 280 GPM starting October 1, 1985. Both events show effects on the other two wells. Well 13 was included in the monitoring network in November, 1984 (Figure 12). A pump test was performed in June, 1985, and is shown on the hydrograph. Water levels during the fall and winter months reflect pumping levels. In all three hydrographs, a dramatic increase in shut-in pressure is evident in July, 1986. At that time, well 9 was rehabilitated with an attendant reduction in leakage.

Well 9 had been flowing for several years at 1500 GPM at the surface and was believed to flow a considerable amount in the subsurface. When drilled in 1970, the flow was estimated to be 2750 GPM and the shut-in pressure was 212 psi. The well was 730 feet deep, completed in rhyolite and was cased to 518 feet in "gray shale and sandstone". There were 300 perforations from 220 to 230 feet and 200 perforations between 460 and 485 feet. The 16 inch steel casing was welded to an 8 inch steel casing at 222 feet. When the well was shut-in during June, 1986, the sound of running water was heard, the well remained warm to the touch, and no response was recorded in wells 11 and 12. All of the above were indications that the well was leaking in the subsurface. It was thought that over the years the pressurized water had eroded the formations around the bottom of the casing and at the perforated intervals. In addition, perforations cut where the 8" casing was welded to the 16 inch casing may have resulted in partial failure of that joint. Cement was pumped into the well to seal the eroded intervals. The well was then redrilled to 743 feet. Casing was set to 640 feet and was pressure-grouted. As soon as the well was controlled at depth, the thermal wells in the vicinity immediately responded. The responses can be seen in the hydrographs of wells 11, 12 and 13 (Figures 10, 11 and 12).

Another well, No. 15, was drilled and completed in December, 1986 and the effects of development are shown in the hydrographs of wells 11, 12 and 13 (Figures 10, 11 and 12). Present usage is less than 10 GPM from this new well. Thus this well has an insignificant effect on the overall system.

## Annual Discharge

To determine the annual discharge from the thermal aquifer, water rights files and field exam reports were reviewed to determine the maximum permitted usage. Based on discussions with well owners pertaining to seasonal and daily consumption, adjustments were made to the maximum permitted amount. Current annual withdrawal of the aquifer within the Twin Falls - Banbury Study Area was estimated to be 23,600 acre feet per year, (4,364 acre feet for the immediate Twin Falls vicinity and 19,326 for the Banbury area).

## PRELIMINARY CONCEPTUAL MODEL OF THE THERMAL SYSTEM

In general, it appears that there are two main directions of flow movement converging in the Twin Falls area: from south to north and from east to west (Young, 1987, personal communication). From the Rock Creek area water follows a generally west-northwest flow path and from the Rogerson area flow is generally to the north. Both flow components encounter the Buhl - Berger Structure Zone in a poorly defined zone southeast of Buhl.

Permeability of the Idavada, both along the flow path and within reservoir rocks, results from fractures related to tectonic movement, sheeted joints and cooling fractures developed during emplacement, intergranular porosity of the non-welded ash flows and air fall tuffs, and voids left between successive flows. Fractures in the BBSZ facilitate the deep circulation of and heating of the water by the regionally high temperature gradient. The heated water is then pushed to the surface in the Banbury area to the northwest by the continued inflow of colder more dense water from the southeast.

It is the authors' opinion based on well testing, similarity of monitoring results, responses to changes in discharge and water chemistry that there appear to be no barriers to thermal water movement within or between the Twin Falls and Banbury portions of the system. While the Twin Falls and Banbury portions of the system are hydrologically connected the source of the heat component at Twin Falls is not clear. The study area is within a zone of regionally high heat flow which extends from northern Nevada to Yellowstone National Park. Heat flow over the zone is generally about 2.5 Heat Flow Units (HFU) (Brott, 1976; Smith, 1980). Lewis and Young (1987, in press) determined heat flow values within the study area to be between 2.2 and 2.5 HFU based on data from thermal gradients derived from bottom hole temperature evaluations. The thermal anomaly over the region is believed to be related to the Cordilleran Thermal Tectonic Anomaly of Eaton and others (1976) and local thinning of the crust related to Basin and Range extension (Mabey, 1983, p. 13). Heat could be conducted through the aquifer from the Banbury area at a greater rate than the inflow of colder water from the southeast. There could also be inflow of thermal water from other systems from the east and northeast, Figure 13.

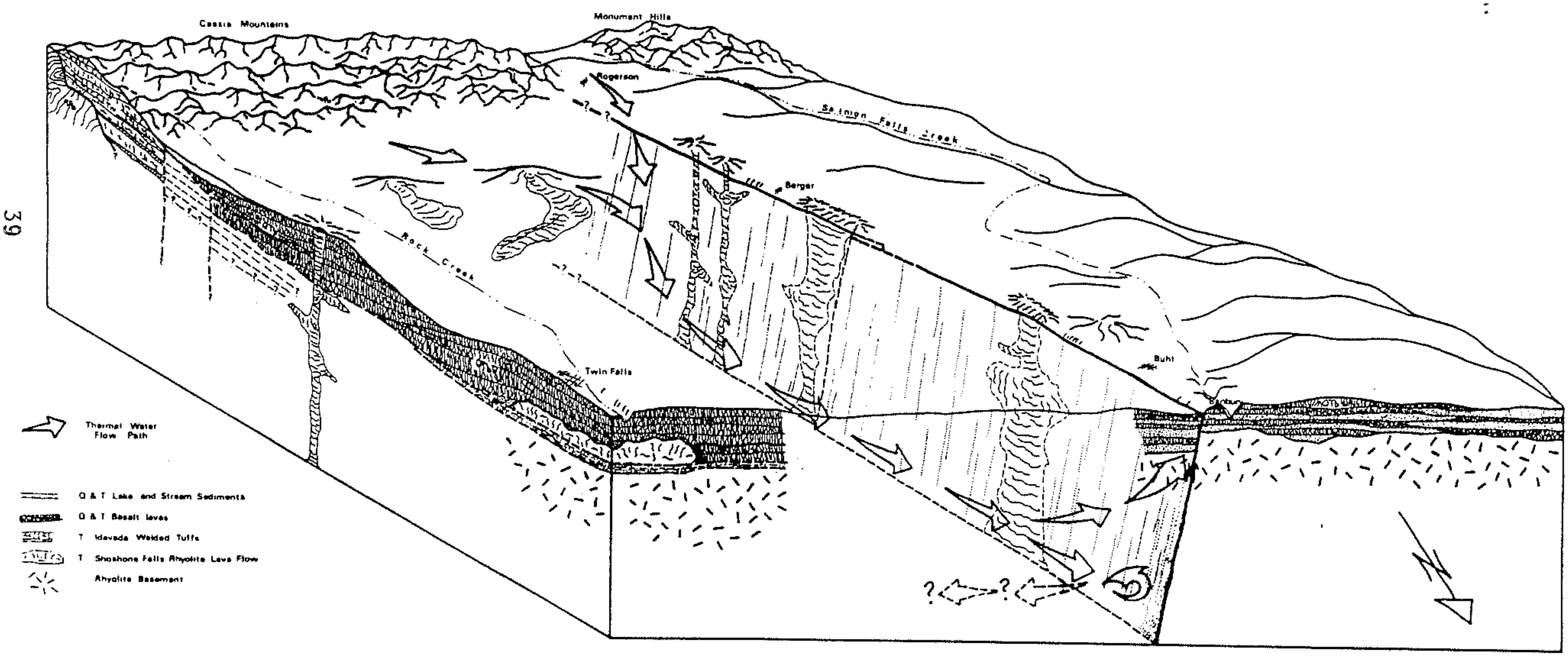



Figure 13. Conceptual Model of the Twin Falls - Banbury Thermal System

## SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDIES

The geothermal resource in the Twin Falls - Banbury area is characterized by temperatures between 30°C and 70°C (86°F to 158°F) and is confined to the Tertiary Idavada rhyolitic rocks. The probable recharge area is the Cassia Mountains where water could circulate to depths via the regional dip of volcanic strata and structure zones and be heated by the regional thermal gradient.

Increased utilization for heating, irrigation, low-head hydro-power production and fish propagation has led to substantial declines in water levels. Monitoring of the aquifer has shown that temperatures remained constant while water levels are still declining and have not reached equilibrium. The seasonal fluctuations indicate response to the decrease in discharge, not necessarily to recharge. The monitoring also demonstrated that the aquifer responds rapidly to the development and usage of new wells or to the repair and shut-in of existing wells, thus indicating good hydraulic interconnection within the Banbury and Twin Falls portions of the system.

This study was initiated to provide baseline data and to develop a preliminary geologic model of the thermal system. During the course of this investigation, several topics for further study were identified:

1. Continued monitoring of the water levels and temperatures of the Twin Falls - Banbury system to expand understanding of the nature and magnitude of declines;

2. Additional chemical analyses of thermal waters to determine if changes have occurred over time as a result of withdrawals.

3. Comparison of regional thermal water chemistries to determine if there are relationships between the Twin Falls - Banbury and adjacent systems.

4. Regional and detailed geologic mapping to: further define the Buhl - Berger Structure Zone, determine if other structures exist that may be related to thermal systems and determine if there are other geologic relationships or boundaries between the Twin Falls - Banbury and neighboring systems.

5. Selected geophysical studies to determine structures at depth and extent of thermal system.

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# APPENDIX A

# DRILLER'S LOGS

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| **T 8S, R 14E, Sec. 30, NESENW (Casing: 8-inch steel 1 to 204 feet)** | | | |
| Elevation: 2906 | | | |
| **Quaternary Alluvium** | | | |
| Brown Clay and Gravel................ | 3 | 0 | |
| Heavy Gravel and Brown Clay.......... | 62 | 3 | Y |
| **Banbury Basalt** | | | |
| Grey Basalt.......................... | 26 | 65 | |
| Grey Clay............................ | 4 | 91 | |
| Brown Clay........................... | 13 | 95 | |
| Grey Basalt.......................... | 30 | 108 | |
| Red Clay............................. | 9 | 138 | |
| Grey Basalt.......................... | 32 | 147 | Y |
| Brown Basalt......................... | 12 | 179 | |
| Grey Basalt.......................... | 35 | 191 | |
| Green Shale w/Grey Basalt............ | 19 | 226 | |
| Green Shale w/Grey Clay.............. | 118 | 245 | |
| Grey Basalt.......................... | 112 | 363 | Y |
| **Idavada Undifferentiated** | | | |
| Grey Shale (major field)............. | 5 | 475 | Y |
| **Total Depth**.......................... | | **480** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 8S, R 14E, Sec. 30, NENWSE
(Casing: 8-inch steel 1 to 80 feet;
6-inch steel 1 to 501 feet)

| Elevation: 2902 | | Water | Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Brown Sandy Clay...................... | 12 | 0 | |
| Gravel................................ | 4 | 12 | Y |
| Gravel and Clay....................... | 16 | 16 | Y |
| Gravel................................ | 23 | 32 | Y |
| **Banbury Basalt** | | | |
| Grey Basalt........................... | 9 | 55 | |
| Brown Scoria and Clay................. | 2 | 64 | |
| Black Basalt.......................... | 19 | 66 | |
| Brown Basalt.......................... | 3 | 85 | |
| Grey Basalt........................... | 9 | 88 | |
| Brown Clay............................ | 5 | 97 | |
| Brown Basalt w/Thin Layers of Sticky Clay..................... | 40 | 102 | |
| Grey Basalt........................... | 31 | 142 | |
| Grey Basalt (Very Hard)............... | 17 | 173 | |
| Red Clay w/Thin Layers of Clay........ | 7 | 190 | |
| Grey Clay............................. | 8 | 197 | |
| Grey Basalt w/Thin Layers of Grey Clay....................... | 22 | 205 | |
| Brown Basalt.......................... | 20 | 227 | |
| Grey Basalt........................... | 11 | 247 | |
| Grey Basalt (Very Hard)............... | 10 | 258 | |
| Grey Basalt w/Green Clay Seams,....... Small Flow, 2 GPM at 268 | 19 | 268 | Y |
| Grey Clay and Sand.................... | 8 | 287 | |
| Coarse Sand and Layers of Shale,...... Flow Increased to 5 GPM | 47 | 295 | |
| Grey-Brown Clay....................... | 23 | 342 | |
| Green Clay............................ | 25 | 365 | |
| Tan Clay.............................. | 11 | 390 | |
| Grey Clay............................. | 8 | 401 | |
| Tan Clay.............................. | 11 | 409 | |
| Grey Clay............................. | 22 | 420 | |
| Tan Clay.............................. | 4 | 442 | |
| Grey Clay............................. Flow picks up to 30 GPM Then Dwindles to 5 GPM | 9 | 446 | Y |
| Light Grey Clay....................... | 60 | 455 | |
| Grey Clay............................. | 32 | 515 | |
| Grey Sand Stone....................... | 31 | 547 | |
| Grey Brown Sand Stone................. | 12 | 578 | |

| | | | |
|---|---|---|---|
| **Idavada Undifferentiated** | | | |
| Black Igneous Rock.................. | 22 | 590 | Y |
| Grey-Brown Igneous Rock............. | 21 | 612 | Y |
| Black Igneous Rock.................. | 67 | 633 | |
| **Total Depth.....................** | | **700** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | T 8S, R 14E, Sec. 30, NWNWSE (Casing: 12-inch steel 0 to 35 feet; 8-inch steel 1 to 145 feet) | | |
| Elevation: 2900 | | | Water -Y/N |
| **Quaternary Alluvium** | | | |
| Top Soil.............................. | 15 | 0 | |
| Medium Hard Rock and Gravel.......... | 10 | 15 | |
| Clay and Rock....................... | 60 | 25 | |
| **Banbury Basalt** | | | |
| Medium Hard Black Rock............... | 25 | 85 | Y |
| Clay and Black Rock.................. | 10 | 110 | |
| Rock and Clay Mix.................... | 60 | 120 | |
| Hard Solid Lava...................... | 35 | 180 | |
| Clay and Water Strips................ | 220 | 215 | Y |
| Clay and Rock Mix.................... | 5 | 435 | Y |
| **Idavada Undifferentiated** | | | |
| Hard Black Rock...................... | 10 | 440 | |
| **Total Depth**..................... | | **450** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | T 8S, R 14E, Sec. 32, SWSENE (Casing: Not on File) | | |
| Elevation: 2950 | | | Water - Y/N |
| **Quaternary Alluvium** | | | |
| Brown Sandy Clay...................... | 3 | 0 | |
| Boulders............................. | 27 | 3 | |
| Grey Sand............................ | 5 | 30 | |
| Boulders, Cobble Stones & Gravel..... | 11 | 35 | |
| Boulders............................. | 6 | 46 | Y |
| Brown Clay........................... | 6 | 52 | |
| Grey Clay & Gravel................... | 6 | 58 | |
| Gravel............................... | 12 | 64 | |
| Brown Clay and Gravel................ | 9 | 76 | |
| **Banbury Basalt** | | | |
| Grey Basalt.......................... | 18 | 85 | |
| Brown Clay........................... | 5 | 103 | |
| Grey Basalt.......................... | 5 | 108 | |
| Brown Clay........................... | 6 | 113 | |
| Grey Basalt.......................... | 38 | 119 | |
| Brown Basalt......................... | 4 | 157 | |
| Red Clay............................. | 8 | 161 | |
| Black Basalt......................... | 26 | 169 | |
| Grey Basalt.......................... | 15 | 195 | |
| Grey Basalt.......................... | 4 | 210 | |
| Grey Clay & Basalt................... | 11 | 214 | |
| Grey Clay............................ | 16 | 225 | |
| Grey Basalt.......................... | 43 | 241 | |
| Dark Grey Clay....................... | 8 | 284 | |
| Grey Shale w/Layers of Sand.......... | 8 | 292 | |
| Grey-Black Basalt.................... | 12 | 300 | Y |
| Dark-Grey Clay....................... | 48 | 312 | |
| Black Basalt......................... | 15 | 360 | |
| Sticky Clay.......................... | 15 | 375 | |
| Grey Shale Clay & Rocks.............. | 17 | 390 | |
| Green Clay........................... | 19 | 407 | |
| Basalt............................... | 2 | 426 | |
| Grey Clay & Shale.................... | 12 | 428 | Y |
| **Idavada Undifferentiated** | | | |
| Black Rhyolite....................... | 31 | 440 | |
| Grey Sand Stone...................... | 40 | 471 | |
| Grey-Brown Rhyolite.................. | 34 | 511 | |
| Brown-Grey Sandstone Shale & Rocks Grey-Green Shale, Rock & Clay... Main Flow | 15 | 545 | Y |

| | | | |
|---|---|---|---|
| Grey Rhyolite........................ | 9 | 560 | Y |
| Grey Clay............................ | 3 | 569 | |
| Light Grey Rhyolite w/Layers of Green Shale.................. | 27 | 572 | Y |
| Light Grey Rhyolite w/Layers Shale........................... | 24 | 599 | |
| Grey Clay Sticky..................... | 6 | 623 | |
| Light Grey Rhyolite.................. | 16 | 629 | |
| **Total Depth.....................** | | **645** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 8S, R 14E, Sec. 32, SENENE
(Casing: 12-inch steel 0 to 49 feet;
8-inch steel 1.5 to 447 feet;
6-inch steel 400 to 815 feet)

| Elevation: 2906 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Sand................................ | 5 | 0 | |
| Sand & Clay......................... | 43 | 5 | |
| **Banbury Basalt** | | | |
| Black Basalt........................ | 78 | 48 | |
| Sandstone........................... | 24 | 126 | Y |
| Sandstone........................... | 40 | 150 | Y |
| Sand, Lots of Water................. | 10 | 190 | Y |
| (Sandstone) Layer of Sand........... | 120 | 200 | Y |
| Sand.......................72°... | 6 | 320 | Y |
| Sandstone..................74°... | 54 | 326 | |
| Sandstone..................80°... | 20 | 380 | Y |
| Sand.......................74°... | 11 | 400 | |
| Rock................................ | 11 | 411 | |
| Sandstone..................74°... | 13 | 422 | |
| Clay.......................74°... | 12 | 435 | |
| Banbury Basalt.............69°... | 33 | 447 | |
| Clay & Basalt....................... | 10 | 480 | |
| Sandstone..................69°... | 30 | 490 | Y |
| Sand.......................82°... | 10 | 520 | |
| Sandstone..................93°... | 105 | 530 | Y |
| Sand.......................104°... | 2 | 635 | |
| Grey Shale.......................... | 3 | 637 | |
| Sandstone........................... | 30 | 640 | |
| **Idavada Undifferentiated** | | | |
| Black or Dark Grey Rhyolite......... | 8 | 670 | |
| Grey Shale.......................... | 4 | 678 | |
| Sandstone........................... | 18 | 682 | |
| Grey Shale.......................... | 42 | 700 | |
| Black Rhyolite...................... | 4 | 742 | |
| Grey Shale.......................... | 14 | 746 | |
| Sandstone........................... | 30 | 760 | |
| Black Rhyolite...................... | 70 | 790 | Y |
| Green-Blue Shale...........108°... | 30 | 860 | |
| Grey Shale.......................... | 40 | 890 | |
| Grey-Black Rhyolite................. | 15 | 930 | |
| Grey Shale.......................... | 2 | 945 | |
| Grey-Black Rhyolite................. | 7 | 947 | |
| Grey-White Shale.................... | 4 | 954 | |
| Dark Grey Shale w/Some of Lighter Grey.................. | 62 | 958 | |

| | | |
|---|---|---|
| Grey-Green Shale.................... | 10 | 1,020 |
| Grey Rhyolite w/Layers of Grey Shale. | 50 | 1,030 |
| Grey Shale & Clay................... | 5 | 1,080 |
| Grey Rhyolite w/Grey Clay............ | 15 | 1,085 |
| Grey Shale.......................... | 20 | 1,100 |
| Grey Rhyolite w/Layers of Clay....... | 30 | 1,120 |
| Grey Shale.......................... | 30 | 1,150 |
| Grey Shale w/White Soft Clay......... | 2 | 1,180 |
| Grey Shale.......................... | 38 | 1,182 |
| Grey/Green Shale.................... | 60 | 1,220 |
| Grey Shale w/Clay Layers............. | 20 | 1,280 |
| Grey Shale w/Thin Clay Layers........ | 80 | 1,300 |
| **Total Depth.....................** | | **1,380** |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | T 8S, R 14E, Sec. 30, NENESW<br>(Casing: 16-inch steel 1 to 23 feet;<br>12-inch steel 1 to 47 feet;<br>6-inch steel 1 to 444 feet) | | |
| Elevation: 2940 | | | Water-Y/N |
| **Quaternary Alluvium** | | | |
| Tan Clay | 15 | 0 | |
| Dark Grey Clay | 9 | 15 | |
| Dark Grey Clay w/ ? | 30 | 24 | Y |
| **Tertiary Basalt** | | | |
| Black Basalt (Hard) | 20 | 54 | |
| Grey Shale | 6 | 74 | |
| Red-Brown Clay | 6 | 80 | |
| Black Basalt | 18 | 86 | |
| Red-Brown Silty Clay | 7 | 104 | Y |
| Red & Black Cinders | 11 | 111 | Y |
| Grey Clay | 84 | 122 | |
| Red Clay w/Rock Layers | 16 | 206 | |
| Grey Basalt w/Clay | 18 | 222 | |
| Grey Basalt (Hard) | 18 | 240 | |
| Grey-Brown Clay | 8 | 258 | |
| Grey-Brown Basalt | 6 | 266 | |
| Grey Basalt | 24 | 272 | |
| Grey Shale | 11 | 296 | |
| Grey Basalt | 2 | 307 | |
| Grey Shale w/Stick Clay | 17 | 309 | |
| Light Tan Shale | 11 | 326 | |
| Grey Clay & Shale | 27 | 337 | |
| Dark Grey Basalt | 3 | 364 | Y |
| Grey Green Shale | 18 | 367 | |
| Grey Shale | 7 | 385 | |
| Green Shale | 7 | 392 | |
| Grey Clay | 33 | 399 | |
| Tan Clay | 9 | 432 | |
| Grey-Green Clay w/Rock Layers | 9 | 441 | |
| Grey-Green Shale w/Rock Layers | 12 | 450 | |
| **Idavada Undifferentiated** | | | |
| Grey Rhyolite | 7 | 462 | Y |
| Grey Shale w/Rock Layer | 15 | 469 | Y |
| Black Rhyolite | 40 | 484 | Y |
| Grey Clay | 4 | 524 | |
| Grey Shale w/Rock Layers | 37 | 528 | Y |
| Black Rhyolite | 22 | 565 | Y |
| Grey Shale w/Clay Layers | 13 | 587 | Y |
| Decomposed Brown Rhyolite (Major Flow) | 10 | 600 | Y |
| **Total Depth** | | **610** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|

T 8S, R 14E, Sec. 32, NENWSE
(Casing: 10-inch steel 1 to 299 feet)

| Elevation: 2931 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Brown Sandy Clay.................... | 6 | 0 | |
| Boulders & Gravel................... | 61 | 6 | |
| Boulders............................ | 16 | 67 | |
| Brown Clay.......................... | 2 | 83 | |
| **Tertiary Basalt** | | | |
| Grey Basalt (Hard).................. | 48 | 85 | |
| Grey Basalt......................... | 5 | 133 | |
| Red Clay............................ | 6 | 138 | |
| Grey Basalt w/Clay Layers........... | 16 | 144 | |
| Grey Basalt (Hard).................. | 32 | 160 | |
| Brown Clay.......................... | 11 | 192 | |
| Grey-Green Clay or Shale............ | 14 | 203 | |
| Black Basalt........................ | 26 | 217 | Y |
| Grey Clay, Shale & Basalt........... | 8 | 243 | |
| Grey Basalt......................... | 16 | 251 | Y |
| Grey Brown Shale.................... | 11 | 267 | Y |
| Black Basalt w/Shale Layers......... | 5 | 278 | |
| Gravel.............................. | 10 | 283 | |
| **Idavada Undifferentiated** | | | |
| Green Shale & Clay.................. | 22 | 293 | |
| Grey Rhyolite....................... | 21 | 315 | |
| Grey Rhyolite & Shale Layered........ | 27 | 336 | |
| Grey-Brown Rhyolite................. | 46 | 363 | |
| Grey Rhyolite....................... | 4 | 409 | |
| Grey Rhyolite (at 435′ Small Flow)... | 105 | 413 | Y |
| Light Shale w/Rhyolite Layered....... | 5 | 518 | |
| Grey Rhyolite....................... | 59 | 523 | Y |
| Grey Rhyolite w/Clay Layers.......... | 30 | 582 | Y |
| Grey Rhyolite....................... | 26 | 612 | |
| Grey Rhyolite w/Clay Layers.......... | 13 | 638 | |
| Green Shale w/Layers of Rhyolite..... | 12 | 651 | |
| Brown Clay (Sticky)................. | 6 | 663 | |
| Black-Brown Rhyolite................ | 16 | 669 | |
| Grey Rhyolite....................... | 11 | 685 | |
| Grey Rhyolite w/Green Shale.......... | 23 | 696 | |
| Black Rhyolite...................... | 35 | 719 | |
| Green Cinders....................... | 4 | 754 | Y |
| Black Rhyolite...................... | 15 | 758 | |
| Grey Rhyolite....................... | 5 | 773 | Y |
| Grey Rhyolite....................... | 4 | 778 | |
| Brown Rhyolite...................... | 24 | 782 | Y |
| Grey Rhyolite....................... | 26 | 806 | Y |
| Grey-Brown Rhyolite................. | 16 | 832 | Y |

| | | | |
|---|---|---|---|
| Grey Rhyolite........................ | 178 | 848 | |
| Black Rhyolite w/clay seams.......... | 13 | 1,026 | |
| Grey Clay............................ | 5 | 1,039 | |
| Black Rhyolite....................... | 8 | 1,044 | |
| Brown Clay (Sticky).................. | 14 | 1,052 | Y |
| Grey Rhyolite w/Layers Sticky Clay... | 9 | 1,066 | |
| Grey Rhyolite........................ | 5 | 1,075 | |
| **Total Depth.....................** | | **1,080** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 8S, R 14E, Sec. 32, NWNWSE
(Casing: 12-inch steel 1 to 39 feet;
8-inch steel 2 to 591 feet)

| Elevation: 2975 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Top Soil............................ | 22 | 0 | |
| Gravel.............................. | 4 | 22 | |
| Clay................................ | 8 | 26 | |
| **Banbury Basalt** | | | |
| Red Lava, (16" to 38′).............. | 67 | 34 | |
| Grey Lava........................... | 124 | 101 | |
| Lava & Clay....................70°... | 6 | 225 | Y |
| Grey Lava........................... | 127 | 231 | |
| Grey Lava, Strips Blue Clay......... | 167 | 358 | |
| Blue Clay......................80°... | 12 | 525 | Y |
| Grey Lava........................... | 35 | 537 | |
| Blue Clay......................86°... | 17 | 572 | Y |
| Grey Lava (12" to 591′)............. | 35 | 589 | |
| **Idavada Undifferentiated** | | | |
| Broken Grey Rhyolite..........110°... | 2 | 624 | Y |
| Hard Red-Brown Rhyolite.............. | 64 | 626 | |
| Hard Grey Rhyolite................... | 183 | 690 | |
| Broken Grey Rhyolite..........120°... | 4 | 873 | Y |
| Hard Grey Rhyolite................... | 25 | 877 | |
| Soft Grey Rhyolite................... | 93 | 902 | |
| Broken Grey Rhyolite..........140°... | 15 | 995 | Y |
| **Total Depth.....................** | | **1,010** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 8S, R 14E, Sec. 33, NWNENW
(Casing: 6-inch steel 1 to 361 feet)

| Elevation: 2900 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Clay | 31 | 0 | |
| Gravel | 2 | 31 | |
| Clay | 92 | 33 | |
| Sand | 15 | 125 | |
| **Banbury Basalt** | | | |
| Black Basalt | 33 | 140 | Y |
| Clay | 47 | 173 | |
| Sand | 25 | 220 | Y |
| Clay | 55 | 225 | |
| Black Basalt | 35 | 280 | |
| Conglomerate | 4 | 315 | |
| Black Basalt (Medium to Hard) | 36 | 319 | |
| Black Basalt (Very Hard) | 100 | 355 | |
| Blue Clay | 117 | 455 | |
| Blue Shale | 86 | 572 | |
| Broken Blue Shale | 12 | 658 | |
| Blue Clay | 145 | 670 | Y |
| Blue Shale (Hard) | 120 | 815 | |
| Blue Clay | 214 | 935 | |
| Blue Shale | 53 | 1,149 | |
| Blue Clay | 40 | 1,202 | |
| **Idavada Undifferentiated** | | | |
| Reddish Brown Rhyolite | 33 | 1,242 | Y |
| **Total Depth** | | **1,275** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| T 8S, R 14E, Sec. 33, NWNWSW<br>(Casing: 10-inch steel 1 to 199 feet;<br>8-inch steel 148.5 to 497.5 feet;<br>6-inch steel liner 494 to 694 feet;<br>Liner is perforated:<br>40 perforations - 497 to 505 feet<br>32 perforations - 674 to 682 feet) | | | |
| Elevation: 2918 | | | |
| **Quaternary Alluvium** | | | |
| Sandy Clay | 13 | 0 | |
| Clay w/Light Grey Sand | 11 | 13 | |
| Sand w/Clay | 19 | 24 | Y |
| Brown Sand w/Small Gravel | 5 | 43 | Y |
| Boulders w/Sand | 4 | 48 | Y |
| Grey Clay | 67 | 52 | |
| **Banbury Basalt** | | | |
| Black Basalt (Hard) | 3 | 119 | |
| Basalt, Broken w/Clay | 17 | 122 | |
| Basalt, Broken w/Clay | 5 | 139 | |
| Basalt, Broken w/Clay | 20 | 144 | |
| Black Basalt (Hard) | 2 | 164 | |
| Grey Clay | 2 | 166 | |
| Brown Clay | 10 | 168 | |
| Black Basalt, Fractured w/Clay | 2 | 178 | |
| Tan Clay | 9 | 180 | |
| Blue-Grey Clay | 3 | 189 | |
| Blue Shale (First Artesian Flow) | 7 | 192 | Y |
| | (Above Flows Grouted Off) | | |
| Blue Shale | 3 | 199 | |
| Black Basalt (Hard) | 1 | 202 | |
| Blue Shale | 10 | 203 | |
| Black Basalt (Hard) | 8 | 213 | |
| Brown Shale | 2 | 221 | |
| Basalt, Broken w/Clay | 12 | 223 | |
| Tan Clay | 5 | 235 | |
| Green Clay | 11 | 240 | |
| Green Shale | 13 | 251 | |
| Grey Clay | 17 | 264 | |
| **Idavada Undifferentiated** | | | |
| Black & Green Rhyolite | 4 | 281 | |
| Light Brown Shale | 4 | 285 | |
| Dark Green Shale | 11 | 289 | |
| Light Grey Clay | 30 | 300 | |
| Green Clay | 4 | 330 | |
| Shale & Green Clay | 37 | 334 | |
| Grey Shale | 13 | 371 | |
| Green Shale | 18 | 384 | |

| | | | |
|---|---|---|---|
| Grey Shale........................... | 24 | 402 | Y |
| Brown Clay........................... | 14 | 426 | |
| Brown Basalt......................... | 4 | 440 | |
| Shale & Green Clay................... | 8 | 444 | |
| Blue Shale........................... | 24 | 452 | |
| Grey Shale........................... | 12 | 476 | |
| Dark Blue Shale...................... | 14 | 488 | |
| Black Basalt......................... | 8 | 502 | |
| Red-Brown Rhyolite................... | 9 | 510 | |
| Black Rhyolite....................... | 3 | 519 | |
| Brown Rhyolite....................... | 5 | 522 | |
| Black Rhyolite....................... | 9 | 527 | |
| Sandstone........................... | 4 | 536 | |
| Black Rhyolite....................... | 7 | 540 | |
| Decomposed Rhyolite, Alternating Hard & Soft Layers.............. | 111 | 547 | |
| Black Rhyolite (Hard)................ | 3 | 658 | |
| Grey Clay............................ | 2 | 661 | |
| Rhyolite (Very Hard)................. | 31 | 663 | |
| **Total Depth......................** | | **694** | |

## LOGS OF WELLS

T 8S, R 14E, Sec. 33, SENWSW
(Casing: 12-inch steel 1 to 119 feet;
8-inch steel 1.5 to 278 feet;
6-inch steel 185 to 470 feet)

Elevation: 2907

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| **Quaternary Alluvium** | | | |
| Brown Clay | 8 | 0 | |
| Brown Sand | 27 | 8 | Y |
| **Tertiary Basalt** | | | |
| Grey Basalt | 13 | 35 | |
| Grey-Brown Clay | 19 | 48 | |
| Grey Basalt | 5 | 67 | |
| Brown Clay | 20 | 72 | |
| Grey Basalt | 45 | 92 | |
| Brown Basalt | 5 | 137 | |
| Grey Basalt | 26 | 142 | |
| Dark Brown Clay | 7 | 168 | |
| Grey Basalt | 34 | 175 | |
| Brown Clay & Brown Basalt | 4 | 209 | |
| Brown Basalt | 6 | 213 | |
| Brown Basalt | 34 | 219 | |
| Green Clay | 4 | 253 | |
| Tan Clay w/Thin Layers of Basalt | 13 | 257 | |
| Tan Clay w/Shale Layers | 36 | 270 | |
| Hard Grey Shale | 21 | 306 | Y |
| Grey-Brown Clay w/Shale in Layers | 25 | 327 | Y |
| Grey-Brown Shale w/Clay in 1′ to 2′ Layers | 26 | 352 | |
| Grey Clay | 31 | 378 | |
| Light Tan Clay | 7 | 409 | |
| Dark Green Shale | 4 | 416 | |
| Light Green Clay | 21 | 420 | |
| Grey-Brown Shale | 9 | 441 | |
| Grey Shale | 20 | 450 | |
| Dark Grey Shale | 17 | 470 | |
| Light Grey Shale | 20 | 487 | |
| **Idavada Undifferentiated** | | | |
| Black Rhyolite | 3 | 507 | Y |
| Brown Rhyolite | 46 | 510 | Y |
| Black Rhyolite | 22 | 556 | Y |
| Grey Shale | 6 | 578 | Y |
| Black Rhyolite | 48 | 584 | Y |
| Black Rhyolite w/Thin Layers of Sticky Clay | 50 | 632 | Y |
| Brown Rhyolite | 61 | 682 | Y |
| Grey-Brown Rhyolite | 57 | 743 | Y |
| **Total Depth** | | **800** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| T 8S, R 14E, Sec. 33, NWNWSW (Casing: 8-inch steel 1 to 259 feet) 6-inch steel 171 to 482 feet) | | | |
| Elevation: 2912 | | | |
| **Quaternary Alluvium** | | | |
| Brown Sandy Clay...................... | 33 | 0 | |
| Brown Clay............................ | 3 | 33 | |
| Brown Sandy Clay...................... | 20 | 36 | |
| Gravel & Sandy Clay................... | 17 | 56 | Y |
| Grey Sand............................. | 39 | 73 | Y |
| Gravel & Boulders..................... | 30 | 112 | Y |
| Grey Sandy Clay....................... | 3 | 142 | Y |
| **Banbury Basalt** | | | |
| Grey Basalt........................... | 3 | 145 | |
| Gravel................................ | 8 | 148 | |
| Brown Clay............................ | 5 | 156 | |
| Gravel & Clay......................... | 25 | 161 | |
| Grey Basalt........................... | 42 | 186 | |
| Brown Basalt & Clay................... | 11 | 228 | |
| Grey Basalt w/Clay.................... | 3 | 239 | |
| Grey Basalt........................... | 29 | 242 | |
| Grey Shale............................ | 14 | 271 | |
| Brown Clay............................ | 16 | 285 | |
| Grey-Green Shale & Clay............... | 57 | 301 | Y |
| Green Shale w/Sand & Gravel........... | 21 | 358 | |
| Gravel................................ | 5 | 379 | |
| Green Shale........................... | 9 | 384 | |
| Green Clay............................ | 24 | 393 | |
| Grey Clay............................. | 31 | 417 | |
| Dark Grey Shale....................... | 6 | 448 | |
| Grey Clay............................. | 16 | 454 | |
| Grey Shale............................ | 48 | 470 | |
| Shale & Sand in Thin Layers........... | 11 | 518 | Y |
| **Idavada Undifferentiated** | | | |
| Black Rhyolite........................ | 53 | 529 | |
| Grey Shale............................ | 5 | 582 | |
| Brown Rhyolite........................ | 53 | 587 | |
| Grey Shale............................ | 14 | 640 | |
| Black Rhyolite........................ | 14 | 654 | Y |
| Black Rhyolite........................ | 19 | 668 | Y |
| Brown Rhyolite........................ | 13 | 687 | Y |
| **Total Depth**....................... | | **700** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 9S, R 14E, Sec. 4, NWNWNW
(Casing: 8-inch steel 0 to 95 feet;
6-inch steel 1 to 215 feet)

| Elevation: 2959 | | | Water - Y/N |
|---|---|---|---|
| **Tertiary Basalt** | | | |
| Sand & Dirt.......................... | 35 | 0 | |
| Decomposed Lava (Medium-Hard)........ | 30 | 35 | |
| Clay & Gravel (Water ?).............. | 75 | 65 | Y |
| **Idavada Undifferentiated** | | | |
| Black Rock (Hard).................... | 110 | 140 | |
| Black Rock (Medium-Hard)............. | 100 | 250 | |
| Grey Rhyolite (Hard)................. | 75 | 350 | Y |
| Broken Spot.......................... | | | |
| Grey Rhyolite (Hard)................. | 155 | 425 | |
| Broken Rhyolite...................... | 5 | 580 | Y |
| Black Rock (Hard) w/Clay Seams....... | 55 | 585 | |
| Black Rock (Hard).................... | 260 | 640 | |
| **Total Depth**...................... | | **900** | |

## LOGS OF WELLS

T 9S, R 14E, Sec. 4, NESESW
(Casing: 8-inch steel 1 to 41 feet;
6-inch steel 1 to 380 feet)

Elevation: 2996

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| **Tertiary Basalts** | | | |
| Dirt & Rock | 6 | 0 | |
| Brown Basalt | 14 | 6 | |
| Grey Basalt | 70 | 20 | |
| Black Basalt & Clay | 5 | 90 | |
| Black Basalt | 25 | 95 | |
| Brown Clay | 11 | 120 | |
| Grey Silt | 42 | 131 | |
| **Undifferentiated Idavada Volcanics** | | | |
| Grey Shale (Hard) | 2 | 173 | |
| Grey Sandy Clay | 50 | 175 | |
| Grey Clay | 23 | 225 | Y |
| Grey Shale (Hard) | 3 | 248 | |
| Grey Clay | 19 | 251 | |
| Grey Shale | 110 | 270 | |
| Brown Shale | 27 | 380 | |
| Grey Shale | 91 | 407 | |
| Black Rhyolite | 104 | 498 | Y |
| Grey Rhyolite | 248 | 602 | |
| **Total Depth** | | **850** | Y |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 9S, R 15E, Sec. 12, SWNESW
(Casing: 8-inch steel 2 to 110 feet;
6-inch steel 30 to 621 feet)

| Elevation: 3065 | | | Water - Y/N |
|---|---|---|---|
| **Tertiary Basalts** | | | |
| Top Soil.............................. | 3 | 0 | |
| Boulders & Gravel..................... | 7 | 3 | |
| Grey Lava............................. | 123 | 10 | |
| Brown Clay............................ | 8 | 133 | |
| Blue Clay............................. | 19 | 141 | Y |
| Brown Sandstone....................... | 44 | 160 | Y |
| **Idavada Pyroclastics** | | | |
| Red Lava.............................. | 4 | 204 | Y |
| Black Lava............................ | 60 | 208 | Y |
| Brown Lava & Red Ash.................. | 11 | 268 | Y |
| Black Lava............................ | 49 | 279 | Y |
| Grey Sand & Blue Clay................. | 39 | 328 | Y |
| Black Lava............................ | 39 | 367 | Y |
| Reddish Brown Lava Ash................ | 14 | 406 | Y |
| Black Lava............................ | 50 | 420 | Y |
| Brown Lava............................ | 130 | 470 | Y |
| Reddish Brown Lava Ash................ | 50 | 600 | Y |
| Sandstone & Clay.................... | 50 | 650 | Y |
| Grey Lava (Hard)...................... | 50 | 700 | Y |
| Blue Clay............................. | 10 | 750 | Y |
| Grey Lava............................. | 75 | 760 | Y |
| Soft Blue Clay........................ | 203 | 835 | Y |
| Hard Rock............................. | 37 | 1,038 | Y |
| Broken Rock........................... | 45 | 1,075 | Y |
| Clay.................................. | 155 | 1,120 | Y |
| Clay.................................. | 9 | 1,275 | Y |
| Hard Black Rock....................... | 16 | 1,284 | Y |
| Black Rock, Layers, Broken............ | 120 | 1,300 | Y |
| **Total Depth** | | **1,420** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| **T 9S, R 17E, Sec. 29, NWNWSE** | | | |
| (Casing: 6-inch steel 0 to 640 feet) | | | |
| Well has been reconstructed. | | | |
| Elevation: 3154 | | | Water - Y/N |
| **Tertiary Basalts** | | | |
| Brown Sand | 7 | 0 | |
| Tan Sandy Clay | 5 | 7 | |
| Boulders in Gravel | 26 | 13 | |
| Loose Basalt | 12 | 39 | Y |
| Basalt Boulders | 7 | 51 | |
| Cinders & Clay | 2 | 53 | Y |
| Basalt Boulders | 10 | 60 | |
| Cinders & Clay | 11 | 70 | Y |
| Basalt Boulders | 6 | 81 | |
| Basalt (Soft) | 37 | 87 | |
| Grey Basalt | 24 | 124 | |
| Brown Basalt | 16 | 148 | |
| Grey Basalt | 29 | 164 | |
| Brown Clay & Rock | 9 | 193 | |
| Brown Basalt | 17 | 202 | |
| Grey Basalt | 34 | 219 | Y |
| Brown Clay w/Rock | 20 | 253 | |
| Grey Basalt | 39 | 273 | |
| Brown Clay | 9 | 312 | |
| Grey Basalt | 40 | 321 | |
| Grey Clay w/Rock | 21 | 361 | |
| Grey Basalt | 6 | 382 | |
| Brown Basalt | 8 | 388 | |
| Grey Basalt | 38 | 396 | |
| Grey Clay | 10 | 434 | |
| Grey Basalt | 15 | 444 | |
| **Lake Sediments** | | | |
| Tan Clay | 8 | 459 | |
| Grey Sandy Clay w/Layered Shale | 11 | 467 | |
| Grey Sand | 2 | 478 | Y |
| **Idavada Pyroclastics** | | | |
| Tan Shale | 6 | 480 | |
| Grey Shale & Sandstone | 32 | 486 | |
| Consolidated Black Shale or Rock(?) | 5 | 518 | |
| Grey Shale | 24 | 523 | Y |
| Brown Rhyolite w/Layers of ? | 58 | 547 | Y |
| Green Rhyolite (Soft) | 25 | 605 | Y |
| Green Rhyolite (Hard) | 20 | 630 | Y |
| Brown Rhyolite (Very Hard) | 35 | 650 | Y |
| Pink Rhyolite (Very Hard) | 15 | 685 | Y |

| | | | |
|---|---|---|---|
| Black & Pink Rhyolite (More Water)... | 2 | 700 | Y |
| Black & Pink Rhyolite (More Water 125 to 175 GPM).................. | 3<br>5 | 702<br>705 | Y<br>Y |
| Pink & Black Rhyolite................ | 15 | 710 | Y |
| Brown & Pink Rhyolite................ | 18 | 725 | |
| Total Depth...................... | | 743 | Y |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 9S, R 17E, Sec. 32, NESESE
(Casing: 12-inch steel 1 to 71 feet;
8-inch steel 2 to 493 feet)

| Elevation: 3637 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary/Tertiary Basalts** | | | |
| Top Soil............................ | 5 | 0 | |
| Lava Boulders....................... | 5 | 5 | |
| Grey Lava........................... | 23 | 10 | |
| Cements (?). Gravel................. | 11 | 33 | |
| Grey Lava........................... | 9 | 46 | |
| Brown Sandy Clay.................... | 4 | 55 | |
| Grey Lava........................... | 12 | 59 | |
| Lava Cinders & Gravel............... | 22 | 71 | Y |
| Brown Lava Cinders.................. | 7 | 93 | |
| Brown Lava Cinders & Clay........... | 40 | 100 | |
| Grey Lava (Hard).................... | 40 | 140 | |
| Brown Clay.......................... | 6 | 180 | |
| Grey Lava........................... | 20 | 186 | |
| Reddish Brown Lava.................. | 49 | 206 | |
| Brown Sandy Clay w/Gravel........... | 24 | 255 | |
| Tan Sticky Clay..................... | 39 | 279 | |
| Grey Lava (?)....................... | 20 | 318 | |
| Brown Sandy Clay.................... | 17 | 338 | |
| Grey Lava........................... | 37 | 355 | |
| Brown Sandy Clay.................... | 63 | 392 | |
| Blue Sticky Clay.................... | 39 | 455 | Y |
| Grey Lava (Hard).................... | 75 | 494 | |
| Reddish Brown Clay.................. | 8 | 569 | |
| Brown Clay.......................... | 48 | 577 | |
| Grey Sandy Clay..................... | 29 | 625 | |
| Brown Sandy Clay.................... | 29 | 654 | |
| **Idavada Pyroclastics** | | | |
| Grey Rhyolite (Hard)................ | 63 | 683 | |
| Reddish Brown (?)................... | 14 | 746 | |
| Grey Rhyolite (Very Hard)........... | 30 | 760 | |
| Black Rhyolite (Hard)............... | 15 | 790 | |
| Rhyolite (Slightly Softer).......... | 15 | 805 | |
| Brown Lava & Clay................... | 20 | 820 | |
| Black Rhyolite (Hard)............... | 20 | 840 | |
| Decomposed Lava..................... | 20 | 860 | |
| Broken Black Rhyolite (Hard)........ | 80 | 880 | |
| Sandstone........................... | 12 | 960 | |
| Sandstone (Very Soft)............... | 2 | 972 | |
| Sandstone, Brown Shale.............. | 53 | 974 | |
| Black Lava.......................... | 33 | 1,027 | |
| Black Rhyolite (Very Hard).......... | 10 | 1,060 | |
| Rhyolite (Slighter Softer).......... | 30 | 1,070 | |

| | | | |
|---|---|---|---|
| Softer Form Again...................... | 7 | 1,100 | |
| Black Rhyolite (Very Hard)........... | 8 | 1,107 | |
| Red & Black Rhyolite................. | 35 | 1,115 | |
| Red & Black Rhyolite (Broken)........ | 15 | 1,150 | |
| Medium-Hard Strips of Soft Broken Rhyolite........................ | 40 | 1,165 | |
| Soft White Shale..................... | 20 | 1,205 | Y |
| Rhyolite, Broken (Medium-Hard)....... | 10 | 1,225 | Y |
| Red Rhyolite, Broken (Soft).......... | 5 | 1,235 | |
| Red Rhyolite, Broken (Hard).......... | 40 | 1,240 | |
| **Total Depth**...................... | | **1,280** | |

## LOGS OF WELLS

T 9S, R 17E, Sec. 33, NWNWNW
(Casing: 24-inch steel 1 to 26 feet;
16-inch steel 1 to 128 feet;
12-inch steel 1 to 261 feet;
8-inch steel 1 to 592 feet)

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| Elevation: 3174 | | | |
| **Bonneville Flood Deposits** | | | |
| Sand & Dirt | 8 | 0 | |
| Grey Lava Boulders & Sand | 18 | 8 | |
| Grey Lava Boulders & Sand | 30 | 26 | |
| Grey Rhyolite Boulders & Cinder Mix | 23 | 56 | |
| **Tertiary Basalts** | | | |
| Grey Basalt (Hard) | 7 | 79 | |
| Grey Rhyolite & Cinders (Soft) | 30 | 86 | Y |
| Grey Lava & Some Clay | 7 | 116 | Y |
| Blue Clay & Lava (Some Caving) | 17 | 123 | |
| Grey Lava (Hard) | 17 | 140 | |
| Grey & Brown Clay/Grey Rhyolite | 10 | 157 | |
| Grey Rhyolite w/Layers of Clay | 36 | 167 | |
| Grey Rhyolite & Clay | 23 | 203 | |
| Grey Basalt (Hard) | 34 | 226 | |
| Grey Basalt (Very Hard) | 14 | 260 | |
| Brown Basalt (Hard) | 6 | 274 | |
| Black Basalt (Hard) | 32 | 280 | |
| Broken Basalt (Crevice) | 2 | 312 | |
| Black Basalt - Some Brown | 1 | 314 | |
| Black Basalt - Big or Broken Boulders | 14.5 | 315 | |
| Grey Basalt (Very Hard) Andesite? | 47.5 | 329.5 | |
| Black Basalt (Andesite?), Broken | 12 | 377 | |
| Black Basalt? Andesite? | 5 | 389 | |
| Black Basalt, Broken | 19 | 394 | |
| Grey Basalt (Very Hard) | 25 | 413 | |
| Broken Basalt (Softer) - Trace of Cold Flowing Water | 14 | 438 | |
| Solid Basalt | 8 | 452 | |
| **Lake Sediments** | | | |
| Layers of Sandstone & Clays - Some Warmer Water | 92 | 460 | Y |
| Layers of Clay & Rock - Water Increasing - About 150 GPM Temp. Increase from 80° to 92° F. | 40 | 552 | Y |

| | | | |
|---|---|---|---|
| **Idavada Pyroclastics** | | | |
| Broken Rhyolite w/Shale Layers - Water Increased about 600 GPM Temp. 99°...................... | 78 | 592 | Y |
| Broken Rhyolite w/Shale Layers -Big Increases in Water Temp., Increased 102°-103°............ | 80 | 670 | Y |
| **Total Depth** | | **750** | |

# LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| T 10S, R 13E, Sec. 20, NESENE (Casing: 20-inch steel 0 to 25 feet; 16-inch steel 0 to 100 feet; 12-inch steel 1 to 255 feet) | | | |
| Elevation: 3428 | | | |
| **Idavada Pyroclastics** | | | |
| Boulders | 25 | 0 | Y |
| Brown Rhyolite | 37 | 25 | |
| Red Clay | 26 | 62 | |
| Loose Rock | 12 | 88 | Y |
| Brown Rhyolite | 48 | 100 | |
| Loose Rock & Clay | 107 | 148 | |
| Brown Rhyolite | 145 | 255 | |
| Grey Rhyolite (Hard) | 62 | 400 | |
| Brown Rhyolite | 18 | 462 | Y |
| Grey Rhyolite | 178 | 480 | |
| Blue Clay (Sticky) | 37 | 658 | |
| Brown Rhyolite | 35 | 695 | Y |
| Brown & Grey Loose Rhyolite | 120 | 730 | Y |
| Grey Rhyolite | 70 | 850 | |
| Red Rhyolite (Loose) | 55 | 920 | Y |
| Grey Rhyolite (Hard) | 65 | 975 | |
| Grey Brown (Loose) | 45 | 1,040 | Y |
| Red Brown (Loose) | 20 | 1,085 | Y |
| Grey Rhyolite (Hard) | 135 | 1,105 | |
| Loose | 27 | 1,240 | Y |
| Hard Rhyolite | 88 | 1,267 | |
| Rhyolite (Broken) | 35 | 1,355 | Y |
| Rhyolite (Hard) | 70 | 1,390 | |
| **Total Depth** | | **1,460** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | | |

T 10S, R 17E, Sec. 4, NESESW
(Casing: 16-inch steel 1 to 367 feet;
12-inch steel 2 to 1611 feet;

| Elevation: 3668 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Basalts** | | | |
| Brown Clay.......................... | 9 | 0 | |
| Black Basalt........................ | 11 | 9 | |
| Brown Silt.......................... | 4 | 20 | |
| Black Basalt........................ | 11 | 24 | Y |
| Brown Silt.......................... | 8 | 35 | |
| Broken Basalt....................... | 4 | 43 | Y |
| Black Basalt........................ | 32 | 47 | |
| Brown Clay.......................... | 3 | 79 | |
| Black Basalt........................ | 21 | 82 | |
| Grey Basalt......................... | 17 | 103 | |
| Brown Basalt........................ | 33 | 120 | |
| Grey Basalt......................... | 9 | 153 | |
| Brown Basalt........................ | 25 | 162 | |
| Grey Basalt (Very Hard)............. | 40 | 187 | |
| Brown Clay.......................... | 5 | 227 | |
| Grey Basalt......................... | 3 | 232 | |
| Brown Clay.......................... | 9 | 235 | |
| Gravel & Brown Clay................. | 39 | 244 | |
| Grey Clay........................... | 22 | 283 | |
| Brown Clay w/Some Gravel............ | 30 | 305 | |
| Grey Basalt......................... | 3 | 335 | |
| Grey Clay........................... | 5 | 338 | |
| Grey Basalt......................... | 74 | 343 | |
| Grey Basalt (Creviced).............. | 8 | 417 | |
| Grey Clay........................... | 8 | 425 | |
| Grey Basalt (Creviced & Hard)........ | 12 | 433 | |
| Grey Basalt (Hard).................. | 50 | 445 | |
| Grey Basalt w/Clay Layers........... | 68 | 495 | |
| Grey Basalt (Very Hard)............. | 7 | 563 | |
| Grey Basalt w/Clay Seams............ | 13 | 570 | |
| Grey Basalt (Hard).................. | 2 | 583 | |
| Grey Clay........................... | 10 | 585 | |
| Grey Basalt......................... | 15 | 595 | |
| Grey Basalt (Hard).................. | 15 | 610 | |
| Brown Clay.......................... | 8 | 625 | |
| **Shoshone Falls Rhyolite** | | | |
| Grey Andesite (Very Hard)........... | 30 | 633 | |
| Grey Andesite (Very Hard)........... | 15 | 663 | |
| Brown Clay.......................... | 9 | 678 | |
| Grey Basalt w/Clay Layers........... | 11 | 687 | |
| Grey Clay........................... | 7 | 698 | |
| Brown Clay & Rocks.................. | 28 | 705 | |

| | | | |
|---|---|---|---|
| Grey Basalt........................... | 17 | 733 | |
| Grey Clay............................. | 35 | 750 | |
| Grey Andesite (Very Hard)............ | 75 | 785 | |
| Grey Clay............................. | 10 | 860 | |
| Grey Rock............................. | 31 | 870 | |
| Grey Clay............................. | 2 | 901 | |
| Grey Rock............................. | 4 | 903 | |
| Clay & Rock in Thin Layers........... | 49 | 907 | |
| Grey Clay............................. | 7 | 956 | |
| Grey Clay (Hard)..................... | 15 | 963 | |
| Grey Rock............................. | 3 | 978 | |
| Grey Clay (Hard)..................... | 11 | 981 | |
| Grey Andesite (Very Hard)............ | 19 | 992 | |
| Sticky Clay........................... | 1 | 1,011 | |
| Grey Andesite (Very Hard)............ | 8 | 1,012 | |
| **Lake Sediments** | | | |
| Brown Clay............................ | 10 | 1,020 | |
| Tan Clay.............................. | 15 | 1,030 | |
| Brown Sand............................ | 5 | 1,045 | |
| Grey-Brown Sand...................... | 20 | 1,050 | |
| Dark Grey Sand w/Some Clay Seams..... | 15 | 1,070 | |
| Dark Grey Sand w/Some ?.............. | 20 | 1,085 | |
| Grey Rock............................. | 2 | 1,105 | |
| Grey Shale............................ | 3 | 1,107 | |
| Grey Rock............................. | 13 | 1,110 | |
| Clay & Sand (First Flow)............. | 2 | 1,123 | Y |
| **Idavada Pyroclastics** | | | |
| Brown Rhyolite....................... | 30 | 1,125 | Y |
| Broken Brown Rhyolite & Sand......... | 15 | 1,155 | Y |
| Brown Rhyolite....................... | 45 | 1,170 | Y |
| (1215 was end of major ?) | | | |
| Red-Brown Rhyolite................... | 335 | 1,215 | |
| Grey-Brown Rhyolite.................. | 105 | 1,550 | |
| Grey Rhyolite........................ | 85 | 1,655 | |
| Grey Rhyolite........................ | 60 | 1,740 | |
| (Reduced hole to 8" at 1760') | | | |
| Grey Rhyolite........................ | 20 | 1,800 | |
| Brown Rhyolite....................... | 17 | 1,820 | |
| Grey Rhyolite........................ | 45 | 1,837 | |
| Grey-Brown Rhyolite.................. | 25 | 1,882 | |
| Brown Rhyolite....................... | 21 | 1,907 | |
| Grey Rhyolite........................ | 34 | 1,928 | |
| Brown Rhyolite....................... | 91 | 1,962 | Y |
| Grey Andesite........................ | 43 | 2,053 | |
| Olivine.............................. | 9 | 2,096 | |
| Grey Andesite........................ | 16 | 2,105 | |
| Light Brown Andesite................. | 66 | 2,121 | |
| Light Brown Rhyolite Crevised........ | 33 | 2,187 | |
| **Total Depth.......................** | | **2,220** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | Water - Y/N |
|---|---|---|---|
| T 10S, R 17E, Sec. 4, SENWSW | | | |
| (Casing: 16-inch steel 1 to 512 feet; 12-inch steel 1 to 1248 feet; 10-inch steel 1184 to 1345 feet; 8-inch steel 1293 to 1453) | | | |
| (Perforations: 16 rows per foot 1293 to 1333; 12 rows per foot 1333 to 1353; 8 rows per foot 1353 to 1453; Size of perforations: 1/4" x 3") | | | |
| Elevation: 3662 | | | |
| **Quaternary and Tertiary Basalt** | | | |
| Brown Clay.......................... | 15 | 0 | |
| Clay & Broken Rock.................. | 7 | 15 | Y |
| Grey Basalt......................... | 23 | 22 | Y |
| Brown Clay.......................... | 4 | 45 | |
| Grey Basalt......................... | 14 | 49 | |
| Clay................................ | 13 | 63 | |
| Grey Basalt......................... | 9 | 76 | |
| Clay................................ | 13 | 85 | |
| Grey-Brown Basalt................... | 32 | 98 | Y |
| Grey Basalt......................... | 34 | 130 | |
| Brown Basalt........................ | 17 | 164 | |
| Grey Basalt......................... | 37 | 181 | |
| Talc................................ | 2 | 218 | |
| Grey Basalt......................... | 21 | 220 | |
| Brown Sandy Clay w/Gravel........... | 137 | 241 | |
| Soft Brown Conglomerate............. | 8 | 378 | |
| Grey Basalt......................... | 30 | 386 | |
| Brown Clay.......................... | 32 | 416 | |
| Grey Clay........................... | 14 | 448 | |
| Brown Clay.......................... | 37 | 462 | |
| Grey Clay........................... | 9 | 499 | |
| Grey Basalt (Hard).................. | 27 | 508 | |
| Brown Clay.......................... | 8 | 535 | |
| Brown Sandy Clay.................... | 97 | 543 | |
| Grey Sandy Clay..................... | 28 | 640 | |
| Grey Sandy Clay..................... | 46 | 668 | |
| Grey Sandy Clay..................... | 8 | 714 | |
| Grey Basalt......................... | 26 | 722 | |
| Reddish Brown Clay.................. | 8 | 748 | |
| Grey Basalt......................... | 22 | 756 | |
| Brown Basalt w/Layers of Sticky Clay. | 5 | 778 | |
| Brown Clay.......................... | 5 | 783 | |

| | | |
|---|---|---|
| Grey Basalt (Hard).................. | 65 | 788 |
| Brown Basalt......................... | 5 | 853 |
| Grey Basalt.......................... | 38 | 858 |
| Grey Clay (Sticky).................. | 16 | 896 |
| **Tertiary Basalt** | | |
| Grey Basalt (Very Hard)............. | 76 | 912 |
| Grey Clay............................ | 2 | 988 |
| Grey Basalt.......................... | 5 | 990 |
| Grey Clay (Sticky).................. | 28 | 995 |
| Grey Basalt.......................... | 5 | 1,023 |
| Clay & Shale w/Fine Gravel.......... | 34 | 1,028 |
| Black Basalt......................... | 8 | 1,062 |
| Brown Clay (Sticky)................. | 12 | 1,070 |
| Grey Clay & Shale (Sticky).......... | 8 | 1,082 |
| Grey Brown Shale.................... | 21 | 1,090 |
| Grey Basalt.......................... | 2 | 1,111 |
| Grey Clay............................ | 1 | 1,113 |
| Grey Basalt.......................... | 8 | 1,114 |
| Grey Clay & Rock Layered............ | 22 | 1,122 |
| Black Basalt......................... | 13 | 1,144 |
| Grey Clay & Shale................... | 19 | 1,157 |
| Grey Basalt.......................... | 5 | 1,176 |
| Grey Shale........................... | 5 | 1,181 |
| Grey Basalt w/Thin Clay Layers....... | 12 | 1,186 |
| Grey Basalt.......................... | 4 | 1,198 |
| Grey Basalt w/Thin Clay Layers....... | 7 | 1,202 |
| Brown Clay........................... | 6 | 1,209 |
| Grey-Brown Basalt................... | 15 | 1,215 |
| Grey Basalt (Hard).................. | 3 | 1,230 |
| Grey-Brown Basalt................... | 15 | 1,233 |
| **Lake Sediments** | | |
| Grey Andesite (Very Hard)........... | 19 | 1,248 |
| Brown Shale (Caved In).............. | 48 | 1,267 |
| Brown Shale.......................... | 6 | 1,315 |
| Layers of Sand, Shale & Clay......... | 14 | 1,321 |
| Light Brown Clay.................... | 15 | 1,335 |
| Brown Rhyolite Chips & Clay.......... | 7 | 1,350 |
| **Idavada Pyroclastics** | | |
| Red-Brown Rhyolite.................. | 123 | 1,357 |
| (Broken 1409-1455) | | |
| 1455 on Broken, Creviced and Caving Formation | | |
| **Total Depth.....................** | | **1,480** |
| Main Flow - 1422' to 1455' | | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| **T 10S, R 17E, Sec. 5, NENESE** | | | |
| (Casing: 12-inch steel 1 to 18 feet; 8-inch steel 2 to 1091 feet; 6-inch steel 1080 to 1200 feet) | | | |
| Elevation: 3647 | | | Water - Y/N |
| **Quaternary and Tertiary Basalts** | | | |
| Top Soil | 3 | 0 | |
| Hard Pan | 13 | 3 | |
| Grey Lava (16" to 19') | 12 | 16 | |
| Brown Ash | 5 | 28 | |
| Brown Lava | 18 | 33 | |
| Brown Cinder | 5 | 51 | |
| Brown Lava (54°) | 84 | 56 | Y |
| Red Lava | 14 | 140 | |
| Brown Lava | 32 | 154 | |
| Grey Lava (54°) | 68 | 186 | |
| Brown Sandy Clay & Gravel | 124 | 254 | |
| Grey Lava (54°) | 26 | 378 | |
| Brown Clay (55°) | 23 | 404 | |
| Blue Clay | 105 | 427 | |
| Grey Lava & Rock | 13 | 532 | |
| White Clay | 3 | 545 | |
| Brown Sandstone | 6 | 548 | |
| Grey Lava | 104 | 554 | |
| Brown Sandstone | 12 | 658 | Y |
| Grey Lava (Very Hard) | 55 | 670 | |
| **Lake Sediments** | | | |
| Brown Clay | 10 | 725 | |
| Blue Clay Shale | 14 | 735 | |
| **Idavada Pyroclastics** | | | |
| Black Rhyolite (63°) | 166 | 749 | |
| Black Lava (Softer) | 23 | 915 | |
| Black Lava (Hard) (63°) | 63 | 938 | |
| Decomposed Lava or Rhyolite | 74 | 1,001 | |
| Brown & Red Sandstone, Broken Rhyolite (85°) | 10 | 1,075 | Y |
| Red Rhyolite (12" to 1091') | 35 | 1,085 | |
| Broken Red Rhyolite (90°) | 3 | 1,120 | Y |
| Red Rhyolite | 27 | 1,123 | |
| Red Rhyolite Sand (90°) | 15 | 1,150 | Y |
| Broken Red Rhyolite | 15 | 1,165 | |
| Red Rhyolite (8" to 1200') | 69 | 1,180 | Y |
| Broken Rhyolite (91°) | 3 | 1,249 | Y |

| | | | |
|---|---|---|---|
| Solid Red Rhyolite.................... | 48 | 1,252 | |
| Broken Red Rhyolite.................. | 5 | 1,300 | |
| Solid Red Rhyolite.................... | 70 | 1,305 | |
| Broken Red Rhyolite.................. | 7 | 1,375 | |
| Solid Red Rhyolite.................... | 68 | 1,382 | Y |
| **Total Depth......................** | | **1,450** | |

Started Flowing 20 GPM at 1,075′
Main Flow From 1180′ to 1,252′

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) |
|---|---|---|

T 10S, R 17E, Sec. 10, NWSENW
(Casing: 16-inch steel 1 to 23 feet;
12-inch steel 2 to 900 feet)

| Elevation: 3717 | | Water - Y/N |
|---|---|---|
| **Quaternary Basalt** | | |
| Top soil............................ | 12 | 0 |
| Grey Lava........................... | 36 | 12 |
| Lava Ash............................ | 5 | 48 |
| Grey Lava........................... | 77 | 53 |
| Red Lava............................ | 7 | 130 |
| Brown Lava.......................... | 8 | 137 |
| Red Lava............................ | 5 | 165 |
| Grey Lava........................... | 68 | 170 |
| Brown Lava.......................... | 20 | 238 |
| Brown Lava.......................... | 5 | 258 |
| **Shoshone Falls Rhyolilte** | | |
| Brown Rhyolite...................... | 11 | 263 |
| Grey Rhyolite....................... | 41 | 274 |
| Grey Rhyolite....................... | 123 | 315 |
| Softer Grey Rhyolite (More Water).... | 20 | 438 |
| Red & Grey Broken Rhyolite - Water... | 13 | 458 |
| Red & Grey Broken Rhyolite - Lots of Water....................... | 47 | 471 |
| Brown Rhyolite...................... | 10 | 518 |
| Broken Grey Rhyolite - Water......... | 3 | 528 |
| Hard Grey Rhyolite.................. | 26 | 531 |
| Broken Softer Red Rhyolite........... | 26 | 557 |
| Solid Grey Rhyolite................. | 4 | 583 |
| Grey Rhyolite (Very Hard)............ | 19 | 587 |
| Broken Brown Rhyolite - Water........ | 6 | 606 |
| Solid Grey Rhyolite................. | 13 | 612 |
| Broken Grey Rhyolite - More Water.... | 13 | 625 |
| Grey Rhyolite (Hard)................ | 60 | 638 |
| Grey Shale (Some Black Rock) - More Water...................... | 16 | 698 |
| Black Rhyolite, Broken - Water....... | 83 | 714 |
| **Lake Sediments** | | |
| Broken Brown Rock................... | 6 | 797 |
| Brown Clay.......................... | 6 | 803 |
| Green Clay & Shale.................. | 33 | 809 |
| **Idavada Pyroclastics** | | |
| Broken Black Rock................... | 28 | 842 |
| Soft Red Rhyolite................... | 9 | 870 |
| Medium Black Rock................... | 31 | 879 |

| | | |
|---|---|---|
| Hard Black Rock...................... | 16 | 910 |
| Soft Brown Rock...................... | 6 | 926 |
| Hard Black Rock...................... | 59 | 932 |
| Soft Brown Sandstone................ | 64 | 991 |
| Grey Decomposed Rhyolite - Hit 81° Water...................... | 30 | 1,055 |
| Grey Decomposed Rhyolite............ | 36 | 1,085 |
| Red Rhyolite......................... | 125 | 1,121 |
| Broken Red Rhyolite - 89°........... | 38 | 1,246 |
| Solid Brown Rhyolite................ | 124 | 1,284 |
| Red Rhyolite......................... | 8 | 1,408 |
| Broken Green & Pink Rhyolite - Some Water...................... | 4 | 1,416 |
| Solid Brown Rhyolite................ | 85 | 1,420 |
| Grey Rhyolite........................ | 195 | 1,505 |
| **Total Depth.....................** | | **1,700** |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) |
|---|---|---|
| | **T 10S, R 17E, Sec. 14, SESWSW** | |
| | (Casing: 6-inch steel 1 to 580 feet) | |
| Elevation: 3786 | | Water - Y/N |
| **Quaternary Basalt** | | |
| Soil | 10 | 0 |
| Hard Pan | 2 | 10 |
| Lava | 37 | 12 |
| Lava Red | 2 | 49 |
| Lava | 10 | 51 |
| Clay & Shale, Medium Flow | 12 | 61 |
| Lava | 4 | 73 |
| Lava (Hard) | 14 | 77 |
| Lava Red, Medium Flow | 3 | 91 |
| Lava (Hard) | 11 | 94 |
| Lava | 16 | 105 |
| Loose Formation - Small Flow | 3 | 121 |
| Lava | 12 | 124 |
| Lava Red | 5 | 136 |
| Lava | 50 | 141 |
| Lava Red - Small Flow | 14 | 191 |
| Lava | 60 | 205 |
| **Piller Falls Mud Flow** | | |
| Boulders - Small Flow | 28 | 265 |
| **Shoshone Falls Rhyolite** | | |
| Lava | 17 | 293 |
| Reaming well from 6 1/4 to 8 1/4 | | |
| Lava (Hard) | 92 | 310 |
| Crevice & Talc | 1 | 402 |
| Lava (Hard) - More Water | 9 | 403 |
| Clay | 4 | 412 |
| Broken Formation of Hard Rock | 2 | 416 |
| Lava | 2 | 418 |
| Clay | 2 | 420 |
| Lava (Hard) | 36 | 422 |
| Clay | 2 | 458 |
| Lava (Hard) | 15 | 460 |
| Lava (Soft) | 3 | 475 |
| Lava (Hard) | 22 | 478 |
| Lava (Soft) | 10 | 500 |
| Lava (Hard) | 68 | 510 |
| Clay | 4 | 578 |
| Blue Clay | 6 | 582 |
| Lava | 12 | 588 |
| Red Lava - More Water | 5 | 600 |
| Black Lava | 22 | 605 |
| Clay | 2 | 627 |
| Lava | 9 | 629 |

| | | |
|---|---|---|
| Clay.................................. | 3 | 638 |
| Lava.................................. | 7 | 641 |
| Lava (Soft) - More Water............. | 3 | 648 |
| Lava (Hard).......................... | 21 | 651 |
| Blue Mud & Clay - More Water......... | 6 | 672 |
| Lava.................................. | 9 | 678 |
| Blue Mud & Boulders.................. | 23 | 687 |
| Rock.................................. | 28 | 710 |
| Blue Clay - More Water............... | 1 | 738 |
| Lava (Hard).......................... | 21 | 739 |
| Lava (Hard) - Reaming Out Wall....... | 70 | 760 |
| Lava (Hard).......................... | 100 | 830 |
| Lava (Hard) - More Water............. | 5 | 930 |
| Lava (Hard).......................... | 45 | 935 |
| **Lake Bed** | | |
| Limestone............................ | 45 | 980 |
| Quartz Crystals...................... | 6 | 1,025 |
| Shale................................. | 24 | 1,031 |
| Lake Bed............................. | 30 | 1,055 |
| **Idavada Pyroclastics** | | |
| Red Granite.......................... | 46 | 1,085 |
| Sandstone - Water Strong............ | 4 | 1,131 |
| Sandstone - Water Strong............ | 19 | 1,135 |
| **Total Depth.....................** | | **1,154** |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) |
|---|---|---|
| T 10S, R 18E, Sec. 6, NWNWNW<br>(Casing: 10-inch steel 1 1/2 to 6 1/2 feet; 8-inch steel 1 to 149 feet; 6-inch steel to 1173 feet) | | |
| Elevation: 3585 | | Water - Y/N |
| **Quaternary Basalts** | | |
| Brown Clay.......................... | 1 | 0 |
| Quaternary Basalt (Hansen Butte)..... | 29 | 1 |
| Light Clay.......................... | 6 | 30 |
| Brown Basalt........................ | 14 | 36 |
| Grey Basalt......................... | 14 | 50 |
| Brown Clay.......................... | 2 | 64 |
| Red-Brown Basalt.................... | 6 | 66 |
| Grey Basalt......................... | 38 | 72 |
| Grey Silty Clay and Gravel.......... | 15 | 110 |
| Brown Basalt........................ | 5 | 125 |
| Basalt (Slightly Green)............. | 5 | 130 |
| Gravel, Silt & Sand................. | 15 | 135 |
| **Shoshone Falls Rhyolite** | | |
| Decomposed Rhyolite................. | 17 | 150 |
| Brown Rhyolite...................... | 202 | 167 |
| Grey-Brown Rhyolite................. | 16 | 369 |
| Grey Rhyolite....................... | 60 | 385 |
| Grey-Brown Rhyolite................. | 20 | 445 |
| Brown Rhyolite...................... | 27 | 465 |
| Grey Rhyolite....................... | 11 | 492 |
| Dark Sand........................... | 4 | 503 |
| Black Rock (Soft & Shiny)........... | 11 | 507 |
| **Lake Sediments** | | |
| Rock and Clay in Layers............. | 19 | 518 |
| Brown Clay.......................... | 9 | 537 |
| **Idavada Pyroclastics** | | |
| Brown Rhyolite...................... | 4 | 546 |
| Brown Clay.......................... | 3 | 550 |
| Grey Rhyolite....................... | 45 | 553 |
| Red-Brown Clay...................... | 4 | 598 |
| Black Rhyolite...................... | 24 | 602 |
| Red-Brown Clay...................... | 5 | 626 |
| Brown Rhyolite...................... | 4 | 631 |
| Tan and Green Shale................. | 21 | 635 |
| Andesite (Very Hard)................ | 89 | 656 |
| Black Rhyolite & Grey Clay in Layers. | 34 | 745 |
| Brown Clay (Sticky)................. | 4 | 779 |
| Andesite & Grey Clay Layered (Very Hard)...................... | 97 | 783 |
| Grey Clay & Shale................... | 13 | 880 |

| | | | |
|---|---|---|---|
| Andesite & Grey Clay Layered | | | |
| (Very Hard)..................... | 22 | 893 | |
| Brown Clay........................... | 5 | 915 | |
| Andesite (Very Hard)................. | 35 | 920 | |
| Brown Clay........................... | 3 | 955 | |
| Grey Rhyolite........................ | 31 | 958 | |
| Grey Clay (Sticky)................... | 6 | 989 | |
| Grey Rock & Clay Seams............... | 39 | 995 | |
| Brown Clay........................... | 6 | 1,034 | |
| Grey Rhyolite........................ | 3 | 1,040 | |
| Brown Clay........................... | 7 | 1,043 | |
| Tan Clay............................. | 15 | 1,050 | |
| Greenish-Grey Shale & Clay........... | 72 | 1,065 | |
| Black Rhyolite....................... | 13 | 1,137 | |
| Clay & Sand Layers................... | 18 | 1,150 | |
| Black Rhyolite....................... | 22 | 1,168 | |
| 1st Flow, Very Small............ | | 1,180 | Y |
| Black Rhyolite w/Thin Layers of | | | |
| Grey Shale...................... | 45 | 1,190 | |
| Grey-Black Rhyolite.................. | 65 | 1,235 | |
| **Total Depth.....................** | | **1,300** | |

## LOGS OF WELLS

| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|

T 10S, R 19E, Sec. 1, SESESE
(Casing: 8-inch steel 0 to 47 feet;
6-inch steel 0 to 1460 feet;
5-inch steel 13 to 1925 feet;
3-inch steel 1900 to 2160 feet
Perforations: 50 - 1400 to 1925 feet;
150 - 2100 to 2160 feet)

| Elevation: 3952 | | | Water - Y/N |
|---|---|---|---|
| **Quaternary Basalt** | | | |
| Brown Clay | 42 | 0 | |
| Grey Basalt | 10 | 42 | |
| Grey Scoria | 31 | 52 | |
| Grey Basalt | 32 | 83 | |
| Grey Scoria | 21 | 115 | |
| Brown Cinders | 34 | 136 | |
| Caving Rock | 10 | 170 | |
| Grey Basalt | 20 | 180 | |
| Black Basalt | 30 | 200 | |
| Brown Scoria | 20 | 230 | |
| Grey Scoria | 18 | 250 | |
| Grey Basalt (Hard) | 6 | 268 | |
| Grey Scoria | 23 | 274 | Y |
| Grey Basalt | 11 | 297 | Y |
| Grey Scoria | 66 | 308 | Y |
| Grey Basalt | 6 | 374 | Y |
| Grey Scoria | 23 | 380 | Y |
| Grey Basalt & Clay | 12 | 403 | Y |
| Brown Basalt | 50 | 415 | Y |
| Grey Basalt | 17 | 465 | Y |
| Brown Clay | 4 | 482 | |
| Brown Basalt | 36 | 486 | |
| Brown Clay | 3 | 522 | |
| Brown Scoria | 3 | 525 | |
| Brown Basalt w/Clay Layers | 13 | 528 | |
| Brown Clay | 8 | 541 | |
| Brown Basalt | 18 | 549 | |
| Brown Clay w/Layers of Basalt | 7 | 567 | |
| Brown Basalt | 31 | 574 | |
| Grey-Brown Basalt | 36 | 605 | |
| Red Clay & Brown Basalt | 23 | 641 | Y |
| Grey-Brown Basalt | 16 | 664 | |
| Grey Basalt | 63 | 680 | |
| Grey Sand | 4 | 743 | |
| Grey Basalt | 17 | 747 | |
| Brown Basalt | 13 | 764 | |

**Idavada Pyroclastics**

| | | | |
|---|---|---|---|
| Grey-Brown Rhyolite.................. | 27 | 777 | |
| Brown Rhyolite....................... | 92 | 804 | |
| Grey Rhyolite........................ | 215 | 896 | |
| Black Rhyolite....................... | 11 | 1,111 | |
| Brown Shale.......................... | 11 | 1,122 | |
| Brown Rhyolite....................... | 9 | 1,133 | |
| Brown Clay........................... | 3 | 1,142 | |
| Brown Rhyolite....................... | 7 | 1,145 | |
| Grey Rhyolite........................ | 13 | 1,152 | |
| Andesite (Very Hard)................. | 9 | 1,165 | |
| Red Clay............................. | 2 | 1,174 | |
| Grey Rhyolite........................ | 7 | 1,176 | |
| Brown Clay........................... | 19 | 1,183 | |
| Grey Rhyolite........................ | 12 | 1,202 | |
| Brown Clay........................... | 3 | 1,214 | |
| Grey Clay & Rhyolite................. | 14 | 1,217 | |
| Grey Rhyolite........................ | 2 | 1,231 | |
| Grey Clay............................ | 42 | 1,233 | |
| Grey Rhyolite........................ | 11 | 1,275 | |
| Grey Clay & Shale.................... | 16 | 1,286 | |
| Grey Rhyolite........................ | 59 | 1,302 | |
| Grey Clay (Sticky)................... | 7 | 1,361 | |
| Grey Sand............................ | 5 | 1,368 | |
| Dark Grey Clay (Sticky).............. | 40 | 1,373 | |
| Grey Sandy Clay...................... | 27 | 1,413 | |
| Tan Clay (Sticky).................... | 6 | 1,440 | |
| Grey Clay (Sticky)................... | 14 | 1,446 | |
| Andesite (Very Hard)................. | 69 | 1,460 | |
| Brown Clay (Sticky).................. | 4 | 1,529 | |
| Sandy Clay........................... | 5 | 1,533 | Y? |
| Red-Brown Sandy Clay................. | 17 | 1,538 | |
| Grey Clay (Sticky)................... | 20 | 1,555 | |
| Grey Shale........................... | 4 | 1,575 | |
| Grey Shale (Sticky).................. | 11 | 1,579 | |
| Grey Clay (Sticky)................... | 5 | 1,590 | |
| Grey Sandy Clay...................... | 5 | 1,595 | Y? |
| Grey Shale........................... | 18 | 1,600 | |
| Grey Clay & Shale.................... | 10 | 1,618 | |
| Black Rhyolite....................... | 42 | 1,628 | |
| Red Clay............................. | 15 | 1,670 | |
| Grey Shale & Clay Layered............ | 15 | 1,685 | |
| Grey Rhyolilte....................... | 5 | 1,700 | |
| Grey Shale........................... | 10 | 1,705 | |
| Grey Rhyolite........................ | 5 | 1,715 | |
| Grey Clay (Sticky)................... | 115 | 1,720 | |
| Light Grey Pumice Clay............... | 8 | 1,835 | |
| Light Green Pumice Clay.............. | 10 | 1,843 | |
| Light Grey Clay (Sticky)............. | 22 | 1,853 | |
| Grey Shale (Caving).................. | 75 | 1,875 | |
| Dark Grey Clay w/Thin Shale Layers... | 39 | 1,950 | |
| Grey Shale........................... | 2 | 1,989 | |
| Dark Grey Clay w/Thin Layers of Shale | 21 | 1,991 | |
| Light Blue-Grey Clay................. | 33 | 2,012 | |

| | | | |
|---|---|---|---|
| Dark Grey Clay...................... | 12 | 2,045 | |
| Dark Grey Shale..................... | 6 | 2,057 | |
| Light Grey Clay..................... | 49 | 2,063 | |
| Light Grey Sand..................... | 7 | 2,112 | |
| Grey Shale w/Alternating Layers of Green Sand..................... | 37 | 2,119 | Y |
| Grey-Green Rock (Rock is fine grained and Very Hard)................. | 4 | 2,156 | |
| **Total Depth.....................** | | **2,160** | |

## LOGS OF WELLS

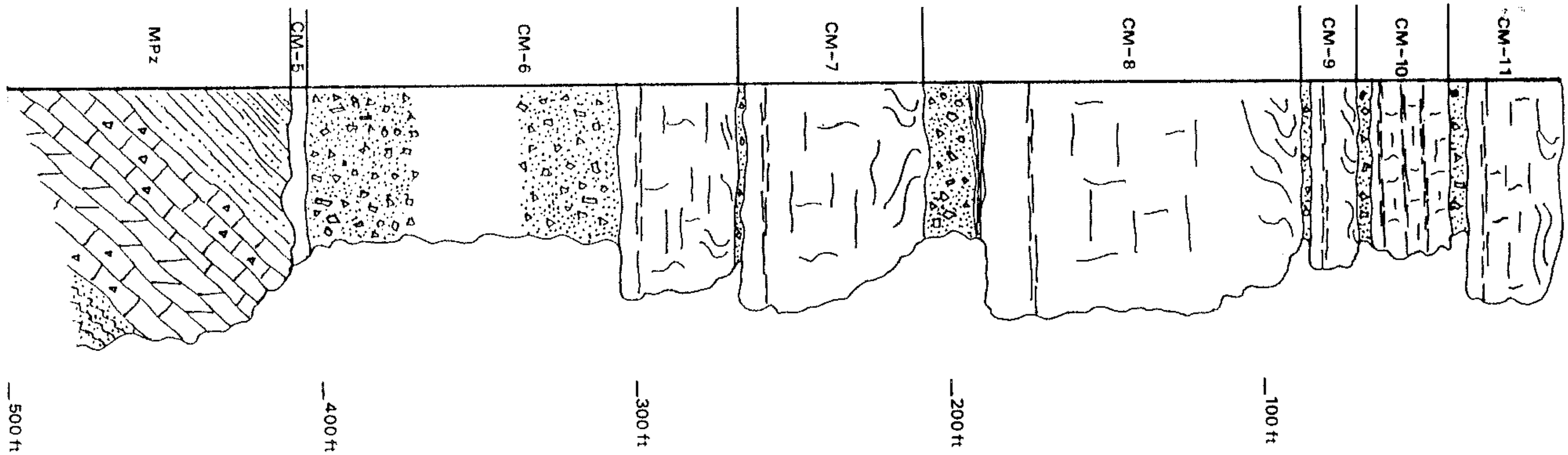
| Material | Thickness (feet) | Depth (feet below land surface) | |
|---|---|---|---|
| | | T 14S, R 15E, Sec. 16, SESWSE (Casing: 8-inch steel 2 to 143 feet) | |
| Elevation: 4931 | | | Water - Y/N |
| **Tertiary Basalts** | | | |
| Top Soil............................ | 5 | 0 | |
| Grey Lava........................... | 22 | 5 | |
| Red-Brown Sandy Clay................ | 32 | 27 | |
| Grey Lava........................... | 56 | 59 | |
| Red-Brown Lava Ash & Cinders........ | 48 | 115 | |
| Brown Clay & Gravel................. | 72 | 163 | |
| Brown Sandy Clay.................... | 45 | 235 | |
| Black Lava Cinders.................. | 32 | 280 | |
| Black Lava (Hard)................... | 11 | 312 | |
| **Idavada Pyroclastics** | | | |
| Brown Rhyolite...................... | 147 | 323 | |
| Broken Brown Rhyolite............... | 65 | 470 | |
| Red Cinders & Talc.................. | 33 | 535 | |
| Grey Rhyolite....................... | 7 | 568 | |
| Broken Red Rhyolite................. | 43 | 575 | |
| Hard Red Rhyolite................... | 17 | 618 | |
| Broken Red Rhyolite................. | 57 | 635 | |
| Brown Clay.......................... | 12 | 692 | |
| Broken Brown Rhyolite & Grey Clay.... | 112 | 704 | |
| Solid Red Rhyolite.................. | 109 | 816 | |
| Solid Grey Rhyolite................. | 51 | 925 | |
| Tan Clay............................ | 24 | 976 | |
| Broken Red Rhyolite & Clay.......... | 60 | 1,000 | |
| Hard Red Rhyolite................... | 22 | 1,060 | |
| Red Clay............................ | 56 | 1,082 | |
| Hard Red Rhyolite................... | 95 | 1,138 | |
| Broken Red Rhyolite................. | 19 | 1,233 | |
| Black Lava.......................... | 8 | 1,252 | |
| Red Lava Ash........................ | 15 | 1,260 | |
| Brown Clay & Lava................... | 32 | 1,275 | |
| Black Sandy Clay.................... | 6 | 1,307 | |
| Brown Rhyolite...................... | 152 | 1,313 | Y |
| Grey Rhyolite....................... | 45 | 1,465 | |
| Red Rhyolite........................ | 30 | 1,510 | |
| Void ............................... | 11 | 1,540 | |
| Crevise and Broken Rock............. | 10 | 1,551 | |
| Hard Rock........................... | 49 | 1,561 | |
| **Total Depth.....................** | | **1,610** | |

# APPENDIX B

# GENERALIZED STRATIGRAPHIC SECTION

# FOR THE

# CASSIA MOUNTAINS




APPENDIX B
Generalized Stratigraphic Section for the Cassia Mountains

Units identified as CM-5 through CM-11 each includes a densely welded rhyolitic ash-flow tuff and the underlying non-welded pyroclastics. All geochemistry samples were taken from densely welded units.

MPz - Pre-Cenozoic marine sedimentary rocks.

# APPENDIX C

## CHEMICAL ANALYSIS OF IDAVADA PYROCLASTICS AND THE SHOSHONE FALLS RHYOLITE TECHNIQUES AND RESULTS

CHEMICAL ANALYSES TABLES

Samples CM10-1, CM10-2, CM9-1, CM9-2, CM11-3, CM11-2, CM11-1, CM10-4 and CM10-3 were analyzed at the University of Utah Research Institute Earth Science Laboratory. The samples were crushed and split in a tungsten carbide shatterbox, pulverized to -200 mesh. The samples were then fused with lithium borate followed by the appropriate dilutions. Major elements, except silica were then analyzed by Inductively Coupled Spectrometry. Silica and the trace elements were analyzed by inductively coupled plasma spectrometry.

Samples CM8-1, CM8-2, CM8-3, CM8-4, CM8-5, CM7, CM5, SF1, SF2 and WC1 were analyzed at Rice University Department of Geology and Geophysics. The samples were crushed and prepared for analysis in the form of lithium metaborate fusion followed by appropriate dilutions. Six of the samples were prepared in duplicate. Major element concentrations were analyzed using Inductively Coupled Spectrometry.

| | CM 11-3 | CM 11-2 | CM 11-1 | CM 10-4 | CM 10-3 |
|---|---|---|---|---|---|
| % oxide | | | | | |
| $SiO_2$ | 70.70 | 73.05 | 66.80 | 65.87 | 73.41 |
| $Al_2O_3$ | 13.00 | 12.24 | 14.87 | 11.83 | 11.71 |
| $TiO_2$ | 0.53 | 0.49 | 0.63 | 0.61 | 0.47 |
| Fe as $Fe_2O_3$ | 4.24 | 3.96 | 4.86 | 4.23 | 3.21 |
| MnO | 0.08 | 0.07 | 0.10 | 0.07 | 0.05 |
| CaO | 1.61 | 1.19 | 1.87 | 4.74 | 1.06 |
| MgO | 0.32 | 0.29 | 0.97 | 0.50 | 0.24 |
| $K_2O$ | 5.27 | 2.91 | 3.88 | 4.10 | 4.00 |
| $Na_2O$ | 3.18 | 3.32 | 2.11 | 2.86 | 2.61 |
| $P_2O_5$ | 0.08 | 0.08 | 0.61 | 0.11 | 0.06 |
| Total | 99.01 | 97.60 | 96.70 | 94.92 | 96.82 |
| LOI | 1.48 | .44 | 2.87 | 3.00 | 1.62 |
| Ba (% oxide) | 0.14 | 0.14 | 0.11 | 0.12 | 0.14 |
| Sr | 103. | 95. | 149. | 143. | 68. |
| Co | 34. | 12. | 7. | 8. | 13. |
| Cu | 6. | 10. | 24. | 10. | 6. |
| Pb | 11. | 14. | 20. | 11. | 18. |
| Zn | 105. | 93. | 103. | 105. | 75. |
| Sb | L30. | L30. | 33. | L30. | 31. |
| Li | 20. | 9. | 34. | 12. | 16. |
| Be | 3. | 3. | 4. | 2. | 3. |
| Zr | 545. | 462. | 470. | 312. | 480. |
| La | 98. | 91. | 92. | 87. | 93. |
| Ce | 173. | 160. | 163. | 143. | 167. |
| F | 670. | 90. | 540. | 340. | 310. |

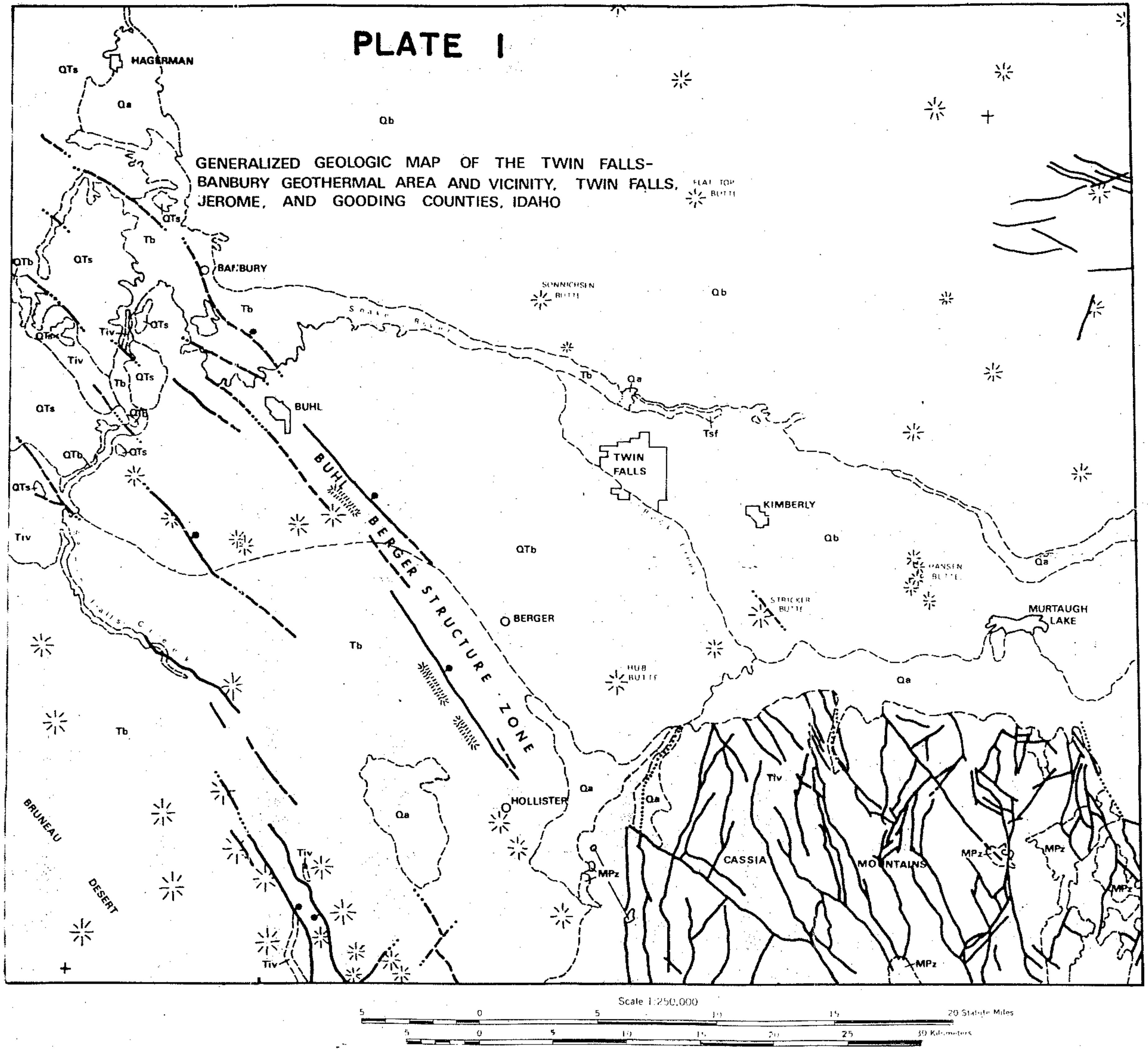
Minor elements in parts per million.

| | CM 8-5 | CM 8-4 | CM 8-3 | CM 8-2 | CM 8-1 |
|---|---|---|---|---|---|
| % oxide | | | | | |
| $SiO_2$ | 73.70 | 74.62 | 73.76 | 71.81 | 73.21 |
| $Al_2O_3$ | 11.84 | 11.64 | 11.90 | 12.71 | 12.21 |
| $TiO_2$ | 0.31 | 0.30 | 0.28 | 0.64 | 0.49 |
| Fe as $Fe_2O_3$ | 2.42 | 2.46 | 2.23 | 4.56 | 2.93 |
| MnO | 0.04 | 0.02 | 0.02 | 0.07 | 0.03 |
| CaO | 0.59 | 0.46 | 0.27 | 1.70 | 0.68 |
| MgO | 0.13 | 0.07 | 0.06 | 0.49 | 0.17 |
| $K_2O$ | 5.66 | 5.28 | 5.34 | 4.38 | 5.91 |
| $Na_2O$ | 2.72 | 3.23 | 3.07 | 3.28 | 2.10 |
| $P_2O_5$ | 0.07 | 0.07 | 0.05 | 0.15 | 0.10 |
| Total | 97.48 | 98.15 | 96.98 | 99.79 | 97.83 |
| LOI | 2.55 | 0.41 | 0.37 | 0.56 | 3.01 |

| | CM 10-2 | CM 10-1 | CM 9-2 | CM 9-1 |
|---|---|---|---|---|
| % oxide | | | | |
| $SiO_2$ | 72.30 | 72.41 | 71.40 | 68.80 |
| $Al_2O_3$ | 11.39 | 11.67 | 12.20 | 12.63 |
| $TiO_2$ | 0.51 | 0.48 | 0.47 | 0.56 |
| Fe as $Fe_2O_3$ | 3.20 | 3.25 | 4.03 | 4.73 |
| MnO | 0.05 | 0.05 | 0.07 | 0.08 |
| CaO | 1.28 | 1.10 | 1.38 | 1.87 |
| MgO | 0.42 | 0.24 | 0.27 | 0.39 |
| $K_2O$ | 4.79 | 5.32 | 3.35 | 4.95 |
| $Na_2O$ | 2.33 | 2.69 | 3.02 | 2.96 |
| $P_2O_5$ | 0.03 | 0.06 | 0.08 | 0.11 |
| Total | 96.30 | 97.27 | 96.27 | 97.08 |
| LOI | 2.62 | 1.50 | 1.70 | 1.28 |
| Ba (% oxide) | 0.12 | 0.14 | 0.13 | 0.14 |
| Sr | 88. | 68. | 82. | 112. |
| Co | 33. | 41. | 11. | 32. |
| Cu | 6. | 6. | 6. | 7. |
| Pb | 15. | 18. | 18. | L10. |
| Zn | 65. | 93. | 93. | 103. |
| Sb | L30. | L30. | 33. | L30. |
| Li | 17. | 16. | 18. | 9. |
| Be | 3. | 3. | 3. | 3. |
| Zr | 436. | 481. | 567. | 554. |
| La | 81. | 92. | 95. | 94. |
| Ce | 141. | 164. | 167. | 163. |
| F | 210. | 310. | 540. | 120. |

Minor elements in parts per million.

| | CM 7 | CM 5 | SF 1 | SF 2 | WC 1 |
|---|---|---|---|---|---|
| % oxide | | | | | |
| $SiO_2$ | 65.21 | 71.93 | 71.54 | 68.65 | 74.72 |
| $Al_2O_3$ | 13.04 | 12.02 | 13.72 | 13.48 | 12.35 |
| $TiO_2$ | 0.77 | 0.43 | 0.69 | 0.69 | 0.36 |
| Fe as $Fe_2O_3$ | 5.34 | 3.57 | 4.66 | 4.69 | 2.95 |
| MnO | 0.08 | 0.04 | 0.07 | 0.07 | 0.05 |
| CaO | 2.45 | 0.87 | 1.82 | 1.98 | 0.61 |
| MgO | 0.74 | 0.20 | 0.72 | 0.67 | 0.17 |
| $K_2O$ | 4.77 | 5.54 | 4.71 | 4.93 | 4.92 |
| $Na_2O$ | 2.88 | 2.44 | 3.53 | 3.17 | 3.39 |
| $P_2O_5$ | 0.22 | 0.08 | 0.18 | 0.16 | 0.06 |
| Total | 95.50 | 97.12 | 101.64 | 98.49 | 99.58 |
| LOI | 1.87 | 2.95 | .36 | 1.75 | .26 |




### Correlation of Map Units

Qa Qb Holocene & Pleistocene — Quaternary

QTs QTb Pleistocene & Pliocene

Tb Tsf Tiv — Miocene — Tertiary

MPz — Mesozoic & Paleozoic

### Description of Map Units

Qa – Quaternary Sedimentary Rocks – Holocene and Pliestocene gravels, sands, silts and clays. Includes Melon Gravel along the Snake River in the western part of the area and Snake River deposits in the east. Also includes large areas of stream and lake deposits along the northern margin of the Cassia Mountains.

Qb – Quaternary Olivine Basalt Lava Flows – Includes flows from Hansen Butte and flows of Snake River Group Basalt from numerous vent areas north of the Snake River Canyon. Many flows show young constructional features such as aa and pahoehoe lava surfaces and pressure ridges.

QTs – Lower Pliocene to Upper Pleistocene Continental Sedimentary Units – Includes stream and lake sediments primarily of the Glenns Ferry Formation. Composed of gravel, sand, silt, clay and interbedded volcanic ash beds.

QTb – Lower Pliocene to Upper Pliestocene Olivine Basalt Lava Flows – Includes flows from Hub Butte and other vents in the southwestern and western part of the area. Some units within the Glenns Ferry Formation are included. Constructional features generally removed by erosion or obscured by loess.

Tb – Lower Miocene to Upper Pliocene Banbury Basalt – Consists of lava flows of olivine basalt locally interbedded with stream and lake sediments. Basalts are commonly altered to greenish brown saprolite with residual spheroids of undecomposed rock. Sediments composed of lenticular channel deposits of sand and pebble gravel and light colored silt, clay and diatomite in massive lake deposits.

Tsf – Rhyolite Lava Flow of Shoshone Falls – Porphyritic light gray devitrified single lava flow. Contains zones of sheeted or platy fractures. Columnar jointing isn't pronounced but strong vertical fractures are abundant. Phenocrysts are predominantly plagioclase with minor amounts of pyroxene and opaque oxides.

Tiv – Welded Ash-Flow Tuff Sheets of the Idavada Volcanic Group – Predominantly densely welded units separated by airfall, water-lain and non-welded ash-flow tuff. Densely welded units are typically zoned from base to top: bedded base surge clastics, basal vitrophere, thick massive central devitrified lithoidal zone, and a thin upper lithoidal vapor phase zone showing prominent flow structures and scattered vitrophere.

MPz – Mesozoic and Paleozoic Marine Sedimentary Rocks of the Cassia Mountains – Includes limestone, dolomitic limestone, siltstone, chert, and quartzite. Formations include lower Triassic Dinwoody, lower Permian Phosphoria and Grandeur Tongue of the Park City and several other locally delineated Permian and possible Ordovician units.

Fault – dashed where inferred or approximately located; dotted where concealed; bar and ball on downthrown side

Geologic contact (all contacts are generalized)

Basaltic vent

Fissure eruption vent